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APPLIED MECHANICS REVIEWS

VOL. 9, NO. 8 MARTIN GOLAND *Editor* AUGUST 1956

RECENT ADVANCES IN SPRAY TECHNOLOGY

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THE process of atomization, which has long been recognized as a vital problem in the field of chemical engineering, has achieved an enviable position of importance in recent years due to the widespread interest in jet propulsion. In this modern application of highly specialized techniques, the combustion of liquid propellants requires that the atomization be fine enough to assure optimum performance in a given combustor, and coarse enough to inhibit the destructive effects of oscillatory combustion. The delicate balance between the opposing requirements of high performance and nondestructive stable combustion demands that the size and distribution of atomized droplets be specified and controlled to within rather narrow tolerances. The problem is further compounded by the conditions imposed by high altitude flight, since both temperature and ambient pressure exert a profound influence on the atomization phenomena. In order to determine the effects of the various physical parameters on the atomization processes, numerous investigations—both theoretical and experimental—have been undertaken, and the results of these studies can be summarized under the following topics:

1. Droplet formation
2. Stream penetration
3. Secondary atomization
4. Evaporation and ballistics.

Since the technical literature abounds with adequate bibliographical surveys on the general subject of atomization (1, 2, 3, 4, 5), the present paper will be limited to a brief description of each topic, followed by a few representative references.

DROPLET FORMATION

The formation of droplets results from the disintegration of a liquid stream or a spray sheet, with the ofttimes observed intermediate configuration of ligaments or "fingers" of liquid. Although the methods for producing these streams or sheets are manifold, the process of disintegration is essentially the same for each; for the phenomena are dependent upon the same physical parameters: the velocity (U), density (ρ), viscosity (η), surface tension (σ), and thickness (b) of the liquid stream, and the corresponding properties of the surrounding medium. From elementary dimensional analysis, it is readily derived that these parameters can be grouped into two independent dimensionless ratios; the Reynolds number (R), which is the ratio of kinetic to viscous forces,

$$R = \frac{\rho U H}{\eta} \qquad [1]$$

and the Weber number (W), which is the ratio of kinetic to surface forces,

$$W = \frac{\rho U^2 b}{\sigma}. \qquad [2]$$

A third dimensionless group which facilitates correlation of atomization data is known as the Ohnesorge number (Z), and is defined as the ratio of the square root of the Weber number to the Reynolds number

$$Z = \frac{W^{\frac{1}{2}}}{R} = \frac{\eta}{(\rho b \sigma)^{\frac{1}{2}}}. \qquad [3]$$

In the discussion which follows, it will be seen that any two of these three dimensionless groups are sufficient to effect correlations of the experimental data on atomization.

The first scientist to make use of these dimensionless groups in analyzing the disintegration of liquid jets was LORD RAYLEIGH (6,7), who provided the fundamental basis for subsequent investigations. As a result of Rayleigh's analyses, which considered both the varicose (radially symmetric) and sinuous (parallel surfaces) disturbances, it was predicted that the wave length of the predominant disturbance will approach zero for liquids of negligible surface tension, and will become infinite for liquids of infinite viscosity. Rayleigh's analyses were extended by WEBER (8), whose theoretical variation of wave length with Weber number for sinuous jets afforded reasonable correlation of the data obtained by MIESSE (9). Similar analyses of spray sheets by SQUIRE (10), YORK, STUBBS, and TEK (11), KELLER AND KOLODNER (12), and HAGERTY and SHEA (13) (whose theory was confirmed experimentally), all demonstrated that the Weber number is the principal factor in jet disintegration. The singular importance of the Weber number in rotating cup atomization was derived theoretically by HINZE and MILBORN (14), whose experimental data confirmed the results of their analysis. Novel disintegration effects were reported by STRAUBEL (15), who effected finer atomization by means of an electrostatic charge across the injector, and MIESSE (16), who reported the dispersing effect of a transverse sound wave and the coalescent effect of an axial wave.

The mean diameter (D) of the spray, which is formed by the disintegration of the liquid jets or spray sheets, is likewise

characterized by the Weber number. The following variation of droplet diameter with the Weber number, as predicted theoretically by HOLROYD (17) and KELLER and KOLODNER (12), was observed for flat sprays by DORMAN (18), for conical sprays by NOVIKOV (19), and for liquid jets by MIESSE (9)

$$\frac{D}{b} = \frac{f(R)}{W^{1/2}} \qquad [4]$$

where $f(R)$ is a function of the Reynolds number which allows for the effects of viscosity. For flat and conical sprays, $f(R)$ was found to be essentially constant, while for liquid jets it was found to be a linear function of the Reynolds number. The inverse variation of average drop size with the square root of the Weber number was reported by WALTON and PREWETT (20) for spinning disk atomization, and by SHAFER and BOVEY (21) for the nozzle atomization data which had been obtained by RUPE (22).

The secondary effect of increased liquid viscosity, which leads to coarser sprays, was reported by GIFFEN (23), RODEAN (24), and MERRINGTON and RICHARDSON (25). A decrease in air density or pressure tends to increase the average size of the drops, as reported by GARNER and HENNY (26) and demonstrated by Miesse's correlation (9). However, if the pressure of the surrounding air is less than the vapor pressure of the liquid, flash vaporization (followed by condensation on dust particles) leads to a fine mist of micron-sized droplets, as noted by SCHMIDT (27).

STREAM PENETRATION

A spray is characterized not only by the size of its droplets, but also by the distance to which it penetrates. The importance of this characteristic is readily recognized, either for those applications which require that a large area be covered by the atomized droplets, or for the operation of combustors, in which the position and nature of the combustion zone becomes a critical factor in their performance. The length of the solid core L, which determines the point at which the individual droplets begin their free trajectories, was found by MERRINGTON and RICHARDSON (25) to vary directly as the square root of the Weber number, while MIESSE (9) reported the secondary importance of the Reynolds number, as predicted by BARON (28):

$$L/b = k\, W^{1/2} R^{-5/8}. \qquad [5]$$

SCHWEITZER (29) noted that tip penetration can be conveniently controlled by injection pressure and orifice diameter, in that it varied directly as the square root of the product of orifice diameter, jet velocity, and time. For spinning disk atomizers, where the spray tip is represented by a ring of droplets, WALTON and PREWETT (20) reported that the radius of the ring varies inversely as the angular velocity of the disk, while the experimental data of MAY (30) indicate that it varies directly as the droplet diameter. Length of the solid core in air atomization was reported by SIESTRUNCK (31) to vary directly as the ratio of the liquid velocity to the relative velocity of the atomizing air.

SECONDARY ATOMIZATION

When a droplet is subjected to a high-velocity air stream, it will be shattered if the kinetic energy of the air stream exceeds the surface energy of the droplet. This shattering of droplets is known as secondary atomization, and the criterion, which was first established by SCHEUBEL (32), leads to the existance of a critical Weber number (W_c). MERRINGTON and RICHARDSON (25) reported a critical Weber number of 64 for falling drops, as compared to MIESSE's (9) figure of 40 for injected drops. This difference can be resolved either by the analyses of HINZE (33, 34), which predict a free-fall/impact ratio of 1.7, or by the criterion of LANE (35), which predicts a ratio of 1.96. A slight modification of this Weber number criterion was introduced by OHNESORGE (36), whose conclusions in terms of the Ohnesorge and Reynolds numbers could be expressed in terms of the critical Weber and Reynolds numbers:

$$W_c = 4.25 \times 10^4 R^{-0.4}. \qquad [6]$$

The phenomenon of air atomization, in which the stream is atomized by a high-velocity air stream, can be analyzed as a secondary atomization process. Thus, BITRON'S (37) data on atomization by means of supersonic air jets revealed that the average drop size varied inversely as the square of the air velocity, as predicted by the concept of the critical Weber number.

EVAPORATION AND BALLISTICS

The ultimate end of the atomization process is to increase the surface-to-volume ratio of the liquid, so that vaporization may proceed more rapidly. Thus, it is of paramount importance to the broad concept of the atomization process that the evaporation characteristics of the liquid be known. Since vaporization is a surface phenomenon, the experimental evidence that the square of the droplet's diameter varies linearly with time is not surprising. The effect of relative velocity on the evaporation rate of a droplet was established by FRÖSSLING (38) and confirmed by RANZ and MARSHALL (39)

$$\frac{d(D^2)}{dt} = \lambda_0 \left[1 + 0.276\,(Sc)^{1/3}\, R^{1/2}\right] \qquad [7]$$

where λ_0 is the evaporation rate in still air, and Sc is the Schmidt number, defined as the ratio of the kinematic viscosity to the diffusion rate of the vapor. HSU, SATO, and SAGE (40) reported that the vaporization of nonspherical drops followed the laws established for spherical drops, and that the over-all vaporization rate increased as the sphericity of the droplet decreased, due to the increase in the surface-to-volume ratio. An increase in the intensity of turbulence in the air surrounding the droplet was found by FLEDDERMAN and HANSON (41) to increase the evaporation rate. The applicability of Frössling's law to droplets injected into an air stream was confirmed by INGEBO (42), and the gross effect of the vaporization of a spray was studied by FOSTER and INGEBO (43), who reported that the concentration of droplet vapors increased as the cube root of the distance from the injector. MIESSE (44) found that this variation could be obtained by plotting the percentage of liquid evaporated upstream of any position versus distance from injector, thus providing a ready method for determining the concentration of vapors surrounding an atomized spray.

The ballistics of droplets, which determines the time-dependent spatial distribution of droplets and vapors, is likewise dependent upon an accurate knowledge of the drag characteristics of a drop. A theoretical analysis by HUGHES and GILLILAND (45) revealed that acceleration drag tended to increase the drag coefficient. For water globules in steam, RYLEY (46) derived an empirical equation for the drag coefficient C_d which approximated Stokes's law for low values of the Reynolds number, and became essentially constant for large values

$$C_d = (0.63 + 4.8/R)^2. \qquad [8]$$

The experiments of INGEBO (42), however, indicated an inverse variation of the drag coefficient with relative velocity, thus suggesting the validity of Stokes's law for the range of variables investigated. The mutual effects of drag and evapo-

ration on the ballistics of a drop were analyzed by MIESSE (47), using Stokes's law and a constant evaporation rate, and were found to be characterized by the ratio of the dynamic viscosity of the air to the product of the density and evaporation rate of the drop. The applicability of this analysis to INGEBO'S (42) velocity data was shown in a second report (48), and the correlation of Ingebo's drop-size histories (42) was achieved by simultaneous solution of Frössling's and Stokes's equations (49).

SPRAY HORIZONS

Although many of the phenomena associated with spray technology have been shown to be amenable to either theoretical or empirical correlation, several areas of this broad field are relatively unexplored: atomization by jet impingement; coalescence of drops; and variation of size distribution with physical parameters. The requirements of upstream turbulence and equality of diameters and momenta for reproducible mixing patterns of two impinging jets were specified by RUPE (50), but no information has yet been reported on the size distributions obtained from this widely-used method of atomization. Although limited investigations of the lower and upper velocity limits for coalescence were conducted by GORBATSCHEW and MUSTEL (51) and GORBATSCHEW and NIKIFOROWA (52), respectively, the data were not sufficiently conclusive to establish any dimensionless criteria.

The most serious deficiency in the present state of spray technology, which offers the broadest horizon for future research, is the absence of a reliable method for predicting the effect of physical parameters on the distribution of drop sizes obtained from a given nozzle. Despite the existence of a multitude of size distribution functions, as summarized by PILCHER et al (2), only the equation derived by TROESCH and GRASSMAN (53) provides explicit expression for the effect of physical parameters. Until the validity of this latter equation is confirmed experimentally, or the use of the standard-size distribution equations is refined beyond its present status as a systematic curve-fitting technique, the concept of size distribution will be of little use to the design engineer.

CONCLUSIONS

As a result of the recent advances in spray technology outlined above, the following conclusions regarding the state of the science of atomization can be drawn:

1. The phenomena of droplet formation, spray penetration, and secondary atomization can be characterized principally by the Weber number, with secondary viscosity effects represented by the Reynolds number.
2. The ballistics of an evaporating droplet is dependent upon the ratio of air viscosity to the product of liquid density and evaporation rate, with the variation of evaporation rate due to relative velocity effects represented adequately by the Schmidt and Reynolds numbers.
3. The relative ignorance in the following fields provides ample opportunity for extensive fundamental research:
   a. Atomization by jet impingement
   b. Coalescence of droplets
   c. Determination of size distribution from physical properties of the liquid, injector, and surrounding atmosphere.

BIBLIOGRAPHY

1 De Juhasz, K. J., The Penn State bibliography on sprays, New York, The Texas Company, 1953.

2 Pilcher, J. M., Miesse, C. C., Benington, F., Weller, A. E., Levy, A., Putnam, A. A., and Landry, B. A., Injection of liquids into gases. Battelle Memorial Institute, WADC Contract no. AF 33(038)-13501, E.O. no. 460-35 S.R.-8, 1951.

3 Giffen, E., and Muraszew, A., The atomization of liquid fuels, New York, John Wiley & Sons, 1953; AMR **7**, Rev. 2642.

4 Marshall, W. R., Jr., Atomization and spray drying, *Chem. Engng. Prog., Monograph Ser.* **50**, no. 2, 1954.

5 Miesse, C. C., From liquid stream to vapor trail, Proc. Gas Dynamics Symposium, Northwestern University, Evanston, Ill., 1956.

6 Rayleigh, Lord, On the instability of jets, *Proc. Lond. math. Soc.* **104**, 1878; see also "Theory of sound," New York, Dover Publications, **II**, pp. 360, 376, 1945.

7 Rayleigh, Lord, On the instability of a cylinder of viscous liquid under capillary force, *Phil. Mag.* **34**, p. 153, 1892.

8 Weber, C., Zum Zerfall eines Flüssigheitsstrahles, *ZAMM* **11**, p. 136, 1931: see English translation, On the breakdown of a fluid jet, Ninth Progress Rept. Project MX-833, Sect. II, Univ. of Colorado, Boulder, Colorado.

9 Miesse, C. C., Correlation of experimental data on the disintegration of liquid jets, *Indust. Engng. Chem.* **47**, p. 1690, 1955; AMR **9**, Rev. 184.

10 Squire, H. B., Investigation of the instability of a moving liquid film, *Brit. J. appl. Phys.* **4**, p. 167, 1953.

11 York, J. L., Stubbs, H. F., Tek, M. R., The mechanism of disintegration of liquid sheets, *Trans. ASME* **75**, p. 1279, 1953; AMR **7**, Rev. 2524.

12 Keller, J. B., and Kolodner, I., Instability of liquid surfaces and the formation of drops, *J. appl. Phys.* **25**, p. 918, 1954; AMR **8**, Rev. 3798.

13 Hagerty, W. W., and Shea, J. F., A study of the stability of plane fluid sheets, *J. appl. Mech.* **22**, p. 509, 1955.

14 Hinze, J. O., and Milborn, H., Atomization of liquids by means of a rotating cup, *J. appl. Mech.* **17**, p. 145, 1950; AMR **4**, Rev. 3293.

15 Straubel, H., Elektrostatische Zerstäubung von Flüssigheiten, *Naturwissenschaften*, **40**, p. 337, 1953.

16 Miesse, C. C., Effect of ambient pressure oscillations on the disintegration and dispersion of a liquid jet, *Jet Propulsion* **25**, p. 525, 1955; AMR **9**, Rev. 793.

17 Holroyd, H. B., On the atomization of liquid jets, *J. Franklin Inst.* **215**, p. 93, 1933.

18 Dorman, R. G., The atomization of liquid in a flat spray, *Brit. J. appl. Phys.* **3**, p. 189, 1952; AMR **5**, Rev. 3448.

19 Novikov, I. I., Atomization of liquids by centrifugal nozzles, *Engineers' Digest* **10**, p. 72, 1949.

20 Walton, W. H., and Prewett, W. C., The production of sprays and mists of uniform drop size by means of spinning disc type sprayers, *Proc. phys. Soc. Lond.* **62**, p. 23, 1949.

21 Shafer, M. R., and Bovey, H. L., Applications of dimensional analysis to spray-nozzle performance data, *J. Res. nat. Bur. Stands.* **52**, p. 141, 1954; AMR **7**, Rev. 3375.

22 Rupe, J. H., A technique for the investigation of spray characteristics of constant flow nozzles, Conference on Fuel Sprays, Univ. of Michigan, Mar. 31, 1949.

23 Giffen, E., Atomisation of fuel sprays, *Engineering, Lond.* **174**, p. 6, 1952; AMR **7**, Rev. 1309.

24 Rodean, H. C., Low temperature fuel spray nozzle tests, *AF tech. Rept.* 6099, USAF, AMC, WPAFB, Ohio.

25 Merrington, A. C., and Richardson, E. G., The break-up of liquid jets, *Proc. phys. Soc. Lond.* **59**, p. 1, 1947.

26 Garner, F. H., and Henny, V. E., Behaviour of sprays under high altitude conditions, *Fuel* **32**, p. 151, 1953.

27 Schmidt, J. M., An experimental study of the behaviour of liquid streams injected into a low-pressure chamber, Jet Propulsion Laboratory Prog. Rept. 4-94, 1949.

28 Baron, T., Atomization of liquid jets and droplets, Univ. Illinois Tech. Rept. no. 4, Feb. 15, 1949.

29 Schweitzer, P. H., Penetration of oil sprays, *J. appl. Phys.* **9**, p. 735, 1938.

30 May, K. R., An improved spinning top homogeneous spray apparatus, *J. appl. Phys.* **20**, p. 932, 1949.

31 Siestrunck, R., Sur Les Regimes de Resolution des Jets Liquides l'influence d'un Souffrage Axial, *C. R. Acad. Sci. Paris* **215**, p. 404, 1942.

32 Scheubel, F. N., On atomization in carburetors, *NACA TM* 644, 1931.

33 Hinze, J. O., Forced deformations of viscous liquid globules, *Appl. sci. Res. (A)* **1**, p. 263, 1948.

34 Hinze, J. O., Critical speeds and sizes of liquid globules, *Appl. sci. Res. (A)* **1**, p. 273, 1948.

35 Lane, W. R., Shatter of drops in streams of air, *Indust. Engng. Chem.* **43**, p. 1311, 1951.

36 Ohnesorge, W. von, Die Bildung von Tropfen an Düsen und die Auflösung flüssiger Strahlen, *ZAMM* **16**, 1936.

37 Bitron, M. D., Atomization of liquids by supersonic air jets, *Indust. Engng. Chem.* **47**, p. 23, 1955; AMR **8**, Rev. 1713.

38 Frössling, N., The evaporation of falling drops, *Gerlands Beitrage Zur Geophysik* **52**, p. 170, 1938.

39 Ranz, W. E., and Marshall, W. R., Jr., Evaporation from drops, *Chem. Engng. Prog.* **48**, pp., 141, 173, 1952.

40 Hsu, N. T., Sato, K., and Sage, B. H., Effect of shape on evaporation of drops, *Indust. Engng. Chem.* **46**, p. 870, 1954; AMR **7**, Rev. 3734.

41 Fledderman, R. G., and Hanson, A. R., The effects of turbulence and wind speed on the rate of evaporation of a fuel spray, Engng. Res. Inst., Univ. of Michigan, Rept. no. CM 667, 1951.

42 Ingebo, R. D., Vaporization rates and drag coefficients for isooctane sprays in turbulent air streams, *NACA TN* 3265, 1954.

43 Foster, H. H., and Ingebo, R. D., Evaporation of JP-5 fuel sprays in air streams, *NACA RM* E55K02, 1956.

44 Miesse, C. C., The combustion of atomized liquid propellants, Symposium on the Literature of the Combustion of Petroleum, 129th A.C.S. Meet., Dallas, Tex., Apr. 1956.

45 Hughes, R. R., and Gilliland, E. R., The mechanics of drops, *Chem. Engng. Prog.* **48**, p. 497, 1952; AMR **6**, Rev. 545.

46 Ryley, D. J., Behaviour of water globules in steam, *Engineer, Lond.* **198**, p. 74, 1954; AMR **8**, Rev. 1224.

47 Miesse, C. C., Ballistics of an evaporating droplet, *Jet Propulsion* **24**, p. 237, 1954; AMR 8, Rev. 2886.

48 Miesse, C. C., Application of droplet ballistics theory to experiments of Ingebo, *Jet Propulsion* **25**, p. 35, 1955.

49 Miesse, C. C., The effect of a variable evaporation rate on the ballistics of droplets, Amer. Rocket Soc. Pap. 223-55, 1955.

50 Rupe, J. H., The liquid phase mixing of a pair of impinging stresses, Jet Propulsion Laboratory Prog. Rept. 20-195, 1953.

51 Gorbatschew, S. W., and Mustel, F. R., Über die untere Stabilitätsgrenze von Tropfen bei ihrem Zusammenprall, *Kolloid Z.* **73**, p. 20, 1935.

52 Gorbatschew, S. W., and Nikiforowa, Über die obere Stabilitätsgrenze von Tropfen bei ihrem Zusammenprall, *Kolloid Z.* **73**, p. 14, 1935.

53 Troesch, H. A., and Grassmann, P., Zum Verteilungsgesetz der Tropfengrössen bei der Zerstaubung, *ZAMP* **4**, p. 81, 1953.

"Letters to the Editor" and "Books Received for Review" now appear after the reviews

Theoretical and Experimental Methods

(See also Revs. 2434, 2443, 2490, 2515, 2574, 2587, 2698, 2703, 2707 2717, 2736, 2747, 2748, 2781)

2423. Afriat, S. N., Simultaneous linear differential equations with constant coefficients, *Proc. Camb. phil. Soc.* **52**, 2, 209-212, Mar. 1956.

It is shown how, under certain conditions of regularity, a system of such equations can be reduced to the vector-matrix form

$$(d\mathbf{U}/dt) + \mathbf{cU} = \mathbf{V}$$

and so solved explicitly. L. M. Milne-Thomson, England

2424. Bodenstedt, E., Analog computer for the differential equation $y'' + f(x)\,y + g(x) = 0$, *Rev. sci. Instrum.* **27**, 4, 218-221, Apr. 1956.

A high-precision electromechanical analog computer is described. The mechanical system is a torsion pendulum. Programmed torques provide an equation of motion which is identical to the equation: $y'' + f(x)y + g(x) = 0$. The solutions are obtained by recording the motion by means of a recording camera. The analog computer is used to study the betatron oscillations and the effects of resonances for the strong focusing Cornell synchrotron. From author's summary

2425. Bellman, R., Perturbation methods applied to nonlinear dynamics, *J. appl. Mech.* **22**, 4, 500-502, Dec. 1955.

It is well known that the convergence and usefulness of a power series is frequently limited by a singular point which is situated outside the domain of interest. If one is interested, for example, in the values of $lg\,(1 + z)$ for positive z only, one is, nevertheless, handicapped by the singularity of the logarithm for $z = -1$ which makes the series diverge for $z > 1$. It is also known that in these cases a simple transformation of z may produce a power series which converges for all positive z.

As perturbation methods are essentially expansions of unknown quantities or functions into power series of a parameter, author suggests the same technique of transformation of the parameter for the improvement of perturbation methods. Applications to algebraic equations, linear and nonlinear differential and integral equations are mentioned, and it is shown how a certain method for the solution of the Van der Pol equation fits into this scheme. H. L. Oestreicher, USA

2426. Rose, A., Johnson, R. C., Heiny, R. L., and Williams, T. J., Computers, mathematics, statistics, and automation, *Indust. Engng. Chem.* **48**, 3 (part 2), 622-632, Mar. 1956.

Fourth annual review of Fundamentals of chemical engineering.

2427. Mudrak, W., Boundary conditions in plane problems with solutions by finite differences (in German), *Bauingenieur* **31**, 1, 20-21, Jan. 1956.

The finite-difference solution of the biharmonic equation is briefly discussed and illustrated with a one-dimensional example.

B. A. Boley, USA

Book—2428. Huntley, H. E., Dimensional analysis, New York, Rinehart & Company, Inc., 1955, ix + 158 pp. $3.50.

This is an American publication of the previous English edition, [see AMR **6**, Rev. 1459]. Book has much to recommend it as a text for undergraduate instruction. Historical background of subject is well covered. Absence of problems for student solution might be regarded as a minor shortcoming. W. J. Carter, USA

2429. Robert, O., Systems of units according to the French and international standards (in French), *Rev. gén. Mécan.* **39**, 83, 409-416, Nov. 1955.

2430. Richards, P. I., Shock waves on the highway, *J. Operat. Res. Soc. Amer.* **4**, 1, 42-51, Feb. 1956.

Author develops a continuous analog for the flow of vehicles along a divided highway. Assuming a linear relation between velocity and density of the "traffic fluid," he shows that the distribution of the vehicle density along the highway at a generic instant may be obtained from the initial distribution by a simple shearing transformation, provided that any multivalued density distribution obtained in this manner is replaced by a distribution containing a density discontinuity. Several instructive problems are solved by this "shear rule"; in particular, the flow through a signalized intersection is treated. While the discussion is less general than that of Lighthill and Whitham [*Proc. roy. Soc.* (*A*) **229**, 317-345, 1955; AMR **9**, Rev. 361], whose paper the author apparently has not seen, the ease with which specific problems can be solved by the shear rule is well worth some loss in generality. W. Prager, USA

2431. Campbell-Allen, D., The theory of sampling applied to concrete control, *Civil Engng. Lond.* **50**, 587, 525-528, May 1955.

The object of the paper is to point out the relationship between test results obtained from samples and the actual properties of concrete, from a statistical standpoint, and to suggest rules for sampling that will enable an engineer to make maximum use of test results and avoid drawing unwarranted conclusions. A general outline of sampling theory as related to concrete production is given, followed by specific steps which can be followed by design and construction engineers. The paper is intended for practical use and is in no way a fundamental contribution to statistical theory. From author's summary

Book—2432. Proceedings of the Eighth International Congress on Theoretical and Applied Mechanics, Istanbul, Turkey, Aug. 20-28, 1952; Vol. I. Istanbul, Faculty of Science, Univ. Istanbul, 1953, 529 pp., printed in 1956.

Volume contains abstracts of contributed papers and program of the Congress. Ed.

Mechanics (Dynamics, Statics, Kinematics)

(See Revs. 2483, 2685, 2689, 2793)

Servomechanisms, Governors, Gyroscopics

(See also Revs. 2444, 2614, 2640)

2433. Reswick, J. B., Disturbance-response feedback—a new control concept, *Trans. ASME* 78, 1, 153–162, Jan. 1956.

Author's concept is that being given a plant (chemical plant, for instance) to try to improve its performance so far as disturbances are concerned. The method particularly applies to a *plant* of the regulator type that has to give a constant output despite disturbances.

The method essentially consists of a double feedback loop; the first loop is the conventional one that compares the output with the input in a differential circuit and amplifies the error (with possible addition of error integral). The second loop adds to the error signal a term equal to the controlled variable that would have been found in absence of disturbances. This signal is obtained by the use of an analog model of the plant. The transfer function of the secondary loop is adjusted in such a way that for steady state its total gain is equal to 1. With this disposition, only the disturbances have to be compensated by the feedback system. A means is provided for continuous adjustment. The system of plant model is particularly fit to solve the case of distance velocity lags in chemical plants.

The system performances have been checked by means of analog computers. They are comparable to those of linear systems including integrators.

Reviewer believes the author must be credited for this new system. Some further paper would be welcome that would include a statement on performances related to elimination of disturbances, since the system is claimed to improve the performance of regulators with respect to disturbances.

J. M. Loeb, USA

2434. Pode, L., The determination of frequency response from test results that are of short duration and not precisely periodic, *David W. Taylor Mod. Basin Rep.* 926, 39 pp., June 1955.

A method of calculation for determining the period, amplitude, and phase of the dominant sinusoidal component of the response of a physical system is given. A moving average is used for elimination of small decaying transients. Detailed discussion included effects of extraneous pulses and sinusoidal components. Analog and digital computational procedures and an example are included. Method is applicable to short tests.

C. L. Perry, USA

Book—2435. Haines, J. E., Automatic control of heating and air conditioning, New York, McGraw-Hill Book Co., Inc., 1953, vii + 370 pp. $6.75.

Book ably describes the "what" and "how" of commercially available automatic controls, together with manner of application in typical installations for buildings. Contents are judged of greatest value for persons desiring controls acquaintance for layout, specification, installation, or service work. Engineers and students desiring introductory acquaintance with air conditioning controls will likewise find the book informative.

Value is greatly enhanced by many sectional drawings of typical controls and the clear schematics illustrating system arrangements. Entire format is excellent.

Technical details are consistently kept within the level of a good course in high school physics or a vocational training institute. Graduate engineers seeking an introduction to controls will be stimulated, however, by recognizing basis for more advanced problems in design and system analysis. There are no equations given beyond Ohm's law. To illustrate the appealing style, the following quotation is taken from discussion of *instability* on p. 340: "When the variation exhibits a definite rhythm, repeating itself over approximately equal periods of time—in a manner analogous to the howling of a telephone when sound waves from the receiver are *fed back* to the transmitter—then it is called *hunting*, as if the thermostat were a hound continually casting back and forth in an attempt to find the lost trail of the fox—the right heating rate."

Scope is well indicated by the titles of the fourteen chapters: (1) Fundamentals of control, (2) Definitions, (3) Fundamentals of measurement, (4) Electric-control circuits, (5) Pneumatic-control circuits, (6) Electric-control units, (7) Pneumatic-control units, (8) Control of domestic heating, (9) Zone control—Commercial heating, (10) Control of unit heaters and unit ventilators, (11) Control of commercial control-fan heating systems, (12) Control of commercial control-fan cooling systems, (13) Control of commercial refrigeration, (14) Control of radiant-panel heating. Some of the material is recognizably based upon manufacturer's manuals.

Book is recommended as a highly companionable addition to a "practical" library. Seekers for advanced demonstrations of system-analysis theory, for electrical-pneumatic-mechanical design analyses applied to control devices, for quantitative performance data, or for newer concepts such as are being developed in aircraft and in some of the processing industries, should, quite properly, look elsewhere.

H. B. Nottage, USA

2436. Watson, E. A., Fuel control and burning in aero-gas-turbine engines. Parts 1, 2, *Engineer, Lond.* **200,** 5213, 5214; 896–899, 928–929, Dec. 1955.

Paper treats a timely and serious control problem. Basic mathematics of controller requirements are reviewed; the special considerations necessary for protective purposes, for handling rapid accelerations and decelerations, and for the changing requirements with flight conditions are discussed. Various mechanizations of controllers of successively increasing complexity and successively improved performance are described. Author's approach represents a change in British practice from calibrated scheduling systems to those employing feedback control principles. Oscillogram data given indicate satisfactory performance of final control design.

Paper is considered to be a significant step in development of aircraft turbine-fuel controls. It is primarily a qualitative treatment and is not highly mathematical.

R. Kochenburger, USA

2437. Mathews, C. W., Adams, J. J., Analytical study of modifications to the autopilot of a fighter airplane in order to reduce the response to side gusts, *NACA TN* 3635, 35 pp., Mar. 1956.

A certain type of autopilot, in which heading commands are applied to the aileron servo, had been found in a previous investigation [*NACA TN* 3603] to have undesirably large roll and yaw response to side gusts. It is shown in the present report that this response can be noticeably reduced by letting the signal from the sideslip vane as well as part of the yaw-rate signal pass through a low-pass filter before applying it to the rudder servo.

From authors' summary by A.I. van de Vooren, Holland

2438. Wiedmann, J. A., and Rowan, W. J., Control-valve plug design, ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55–A–103, 7 pp. + 1 table + 9 figs.

With the aid of a few basic flow relationships and a series of empirical coefficients, it is possible to design a control-valve plug which will have a predetermined flow characteristic. It has been found that the friction losses in the valve body cannot be neglected in such a design, and that the efficiency of the valve-port opening also must be included. In this paper, a contoured plug has been designed with an equal percentage characteristic for a 2-in. top and bottom-guided, single-seated, globe-type valve. The paper also includes the results of a flow test on a plug made according to this design, plus a discussion of the principal limitations associated with this general approach.

From authors' summary

2439. Ward, J. T., Procedures for evaluation of control-valve mechanical characteristics, ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55–A–105, 6 pp. + 4 figs.

2440. Bremer, A., Procedures for evaluating dynamic characteristics of valve operators, ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55–A–110, 6 pp.

A description of the test equipment necessary for making step and frequency-response tests on pneumatic valve motors is given, together with details of its operation. The test procedures are discussed in detail for conditions encountered in the laboratory and in the field, with

reasons for each. Finally, the practical value of such tests is demonstrated with a few examples concerning the use of valve positioners or booster relays. From author's summary

2441. Gorrie, H. H., and Gantz, W. L., Practical limitations of current materials and design of control valves, ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55-A-113, 9 pp.

2442. Johnson, C. M., and Fallis, J. M., Test procedures for the evaluation of control valve flow performance, ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55-A-152, 7 pp. + 1 table + 8 figs.

Different methods have been used to establish ratings for the maximum capacity and flow characteristics of control valves. These methods and the equipment used are described. It is pointed out that the use of different methods will result in differences in valve ratings. The necessity for standardized procedures for testing and rating control valves is discussed. From authors' summary

Vibrations, Balancing

(See also Revs. 2467, 2515, 2616, 2774)

2443. Synge, J. L., Stationary principles for forced vibrations in elasticity and electromagnetism, *Nat. Bur. Stands. Rep.* no. 4582, 19 pp., Mar. 1956.

Chief objective of this brief, highly mathematical paper is the interpretation in geometrical form of certain stationary principles already known. This is accomplished by using concept of function-space with suitable scalar product which, for forced vibration problems, provides an indefinite metric. Author states that detailed account of these methods, with numerous applications, will be given in forthcoming book: J. L. Synge, "The hypercircle in mathematical physics," Cambridge University Press. C. W. Smith, USA

2444. Neimark, Yu. I., Natural and forced vibrations in time-delay relay systems (in Russian), *Avtomatika i Telemekhanika* **16,** 3, 225–232, 1955.

This paper is a continuation of an earlier paper by the same author [title source, no. 5, 1953] which has not been available to the reviewer. Author shows that the method of his afore-mentioned paper is suitable for investigation of periodic solutions of time-delay relay systems. Only the simplest symmetric periodic motion of such a system is considered. The equation of motion and the characteristic function are first derived in general, and are then specified for natural and forced vibration of the system. The stability of periodic solutions depends upon the disposition of roots of the characteristic function with respect to the unit circle in the complex plane. The theory is illustrated by an example.

E. Leimanis, Canada

2445. Klotter, K., Free oscillations of systems having quadratic damping and arbitrary restoring forces, *J. appl. Mech.* **22,** 4, 493–499, Dec. 1955.

The quadratic damping forces are of any magnitude and the restoring forces of any type. Differential equations of motion are transformed into linear differential equations of first order for the velocity squared. A first integral can be obtained readily. From it, the exact relationships between any two consecutive maximum displacements (amplitudes) are derived. These relationships are discussed in detail for various types of restoring forces. Examples are worked out numerically and illustrated by graphs.

Contrary to earlier paper, author considers nonlinear restoring forces. He also realizes that, particularly if these forces are not linear, one need not shy away from approximating a damping force-velocity relationship by quadratic expression, all the more as quadratic damping forces allow exact procedures. In certain instances, other types of damping forces may be replaced by "equivalent qaudratic" ones.

S. T. A. Ödman, Sweden

2446. Arnold, F. R., Steady-state behavior of systems provided with nonlinear dynamic vibration absorbers, *J. appl. Mech.* **22,** 4, 487–492, Dec. 1955.

Author studies the response of vibrating systems under the action of sinusoidal forces and of nonlinear dynamic vibration absorbers. The Ritz averaging method for dynamical systems of a single degree of freedom having various types of nonlinearities is extended to multi-degree-of-freedom systems (particularly to two-degree-of-freedom systems). Author naturally includes in the system studied the nonlinear dynamic vibration absorber and concludes that one of the most striking characteristics of system response is the apparent existence of up to three modes of oscillation for a single value of disturbance frequency. The problem of stability is also discussed.

A. Pignedoli, Italy

2447. Hayes, W. D., and Miles, J. W., The free oscillations of a buckled panel, *Quart. appl. Math.* **14,** 1, 19–26, Apr. 1956.

The nonlinear equations of motion of a buckled, two-dimensional panel are formulated in dimensionless form. A Fourier expansion in the space variable is introduced and an approximate solution is obtained for the period of free oscillation on the assumption of only two degrees of freedom, one of which is eliminated by the buckling constraint. The periods of the simplest asymmetric and symmetric modes are plotted as a function of the energy level. It is found that for very small energy levels the period of the buckled panel lies between the periods of the (two) unbuckled degrees of freedom. As the energy is increased, the period approaches infinity at some critical energy level and thereafter decreases monotonically.

From authors' summary by M. V. Barton, USA

2448. Martin, A. I., On the vibration of a cantilever plate. *Quart. J. Mech. appl. Math.* **9,** 1, 94–102, Mar. 1956.

Approximate solution for the frequencies of vibration of rectangular cantilever plates. Utilizing the variational procedure, the deflection function $w(x,y)$ is represented by $w = u(x)\,v(y)$, where $v(y)$ are normal modes of free-free beams. Imposing the condition that u and u' are zero along the clamped edge results in an ordinary differential equation. This is solved with boundary conditions of zero moment and shear along the free edge. Frequencies are computed for a particular plate and results are compared with experiment, with good results.

This problem has been solved by Barton [AMR **4,** Rev. 4079] using the Rayleigh-Ritz procedure, but the present paper has the advantage of involving less computational effort. It would have been interesting to compare numerical results obtained from the two methods.

H. Lurie, USA

2449. Eringen, A. C., On the nonlinear oscillations of viscoelastic plates, *J. appl. Mech.* **22,** 4, 563–567, Dec. 1955.

Author formulates a second-order theory for transverse motion of viscoelastic plates. The components of displacement are assumed to have power-series expansions in the transverse coordinate and a perturbation procedure in a nondimensional thickness parameter is used. Author uses a special linear stress-strain relation containing linear operators in the time derivative, but does not discuss the consistency of these equations with the rest of the theory. Final equations are complicated and, although further simplifications are mentioned for flexural vibrations, no applications are made to special problems.

A. E. Green, England

2450. Yu, Y.-Y., Free vibrations of thin cylindrical shells having finite lengths with freely supported and clamped edges, *J. appl. Mech.* **22,** 4, 547–552, Dec. 1955.

Free vibrations of thin cylindrical shells are considered for (a) freely supported ends, (b) clamped ends, (c) one end freely supported, one clamped. Each condition shows existence of three frequencies for any nodal pattern. Method is based on Donnell's equations. Assumption is made that circumferential wave length is small compared with axial wave length. Frequencies for case (a) are compared with those from other methods.

Reviewer considers foregoing assumption limits the use of the method. R. N. Arnold, Scotland

2451. Hearmon, R. F. S., and Adams, E. H., The flexural vibrations of an end-loaded vertical strip, *Brit. J. appl. Phys.* **6,** 8, 280–284, Aug. 1955.

Rayleigh-Ritz method is used to obtain a close upper bound to the

lowest natural frequency of a vertical cantilever with tip mass. Rotatory inertia of tip mass is accounted for. The final formula permits an experimental determination of Young's modulus more accurate than results from the use of the conventional cantilever formula.

L. E. Goodman, USA

2452. Ekstein, H., and Schiffman, T., Free vibrations of isotropic cubes and nearly cubic parallelepipeds, *J. appl. Phys.* **27,** 4, 405–412, Apr. 1956.

Free vibrations of isotropic cubes and nearly cubic parallelepipeds are derived by a modification of the Ritz method. The trial functions are chosen to be similar to actual modes; some by the semidirect method of variational calculus, others as simple solutions of somewhat different elastic problems. By the use of group theory, the frequency equation is solved rigorously. Some unexpected degeneracies are explained. The illustrations (Figs. 1–13) are exceptionally well done and significant.

G. Sestini, Italy

2453. Geiger, J., Vibration of frame structures (in German), *ZVDI* 98, 7, 261–266, Mar. 1956.

Paper is written for structural engineers who require elementary approximate methods to find natural frequencies of turbine foundations. Starting from the differential equation of a vibrating member, frequency equations for simple frames are derived; two charts for horizontal vibrations are given. Effects of shear and longitudinal deformations and of variations in cross section are discussed. Tests on columns and frames were made and good agreement between analysis and tests is claimed.

H. Bleich, USA

2454. Caruso, W. J., How to lick turbine-bucket vibrations, *Power* 100, 4, 80–83, 210–212, Apr. 1956.

2455. Downham, E., The critical whirling speeds and natural vibrations of a shaft carrying a symmetrical rotor, *Aero. Res. Counc. Lond. Rep. Mem.* no. 2854, 13 pp., 1954.

The experiments described are part of a program of model experiments designed to establish an accurate method for calculating the critical whirling speeds of complex systems.

The critical whirlings speeds and natural vibrations of a single shaft flexibly supported and carrying a flexible rotor of appreciable moment of inertia have been investigated and good agreement has been obtained between experimental and calculated results for the rotating system. There is some discrepancy between calculated and experimental results for the vibration of the nonrotating system, which is thought to be due to the operational characteristics of the flexible bearing.

From author's summary

2456. Payne, P. R., The control of helicopter rotor vibration, *J. Helicop. Assn.* **9,** 3, 327–368, Jan. 1956.

2457. Kolesnikov, K. S., Interpretation of the experimental curves of attenuating vibrations by I. Newton's method (in Russian), *Inzhener. Sbornik, Akad. Nauk SSSR* no. 20, 164–167, 1954.

Author considers damped free vibrations of single-degree-of-freedom system with damping a polynomial function of velocity, $F(v)$. Following Newton, he points out that if a and b are the excursions on positive and negative sides of equilibrium, respectively, in adjacent half cycles, then $a - b = f(a + b)$, where f is the same form of polynomial as F. Relations are then developed connecting measurements of $(a + b)$ over a series of half cycles and of the amplitude decrement every two cycles on an oscillographic record, from which $F(v)$ may be evaluated. Typical test record is worked out in detail.

W. W. Soroka, USA

2458. von Weiss, A., Vibration-free erection and design of measuring instruments (in German), *ZVDI* **98,** 6, 205–208, Feb. 1956.

2459. Anonymous, Gyrostatic torque, *Engng. Dig., N. Y.* **2,** 3, 31–32, Mar. 1956.

This discussion originated in some investigations of determining the critical speeds of a turbo-alternator of the Ljungstrom type, and article is published with the permission of the British Electrical Engineering Co. Ltd. Presented is a simple alternative method of deducing the gyrostatic torque exerted on its supporting shaft by a rotating solid revolution. The motion of the rotating body is considered by reference to a set of moving rectangular axes. Forward and backward precession are comprised in a single result.

From summary

2460. Franke, P., Calculation of oscillations in waterlocks (in German), *Bauingenieur* **31,** 3, 93–96, Mar. 1956.

2461. Yorgiadis, A., Two-degree-of-freedom vibration nomogram, *Prod. Engng.* **26,** 1, 205–207, Jan. 1955.

Wave Motion in Solids, Impact

(See also Rev. 2650)

2462. Boley, B. A., and Chao, C. C., Some solutions of the Timoshenko beam equations, *J. appl. Mech.* **22,** 4, 579–586, Dec. 1955.

Laplace transformation method is used to arrive at solutions to semi-infinite beam problems involving four different end loadings; namely, step velocity and zero bending moment, step bending moment and zero displacement, step angular velocity and zero shear force, and step shear force and zero rotation. Some numerical results are discussed and compared with corresponding solutions from the elementary bending theory. In the first problem, with the aid of the Duhamel integral, numerical results are also obtained for the shear force relating to gradually applied loads.

The numerical results for the shear force (at particular beam stations) point out, for both the step and gradually applied loads, disagreement of the theories for the early times and fair agreement for the later times. At the origin station, better agreement for the early times occurs when the load rises more slowly.

Although the basic technique used here for solving the Timoshenko bending equation has already appeared in the literature, the particular problems solved and discussed by the authors add to our knowledge on flexural wave propagation.

J. Miklowitz, USA

2463. Krafft, J. M., Elimination of the transient strain fluctuations which result from longitudinal impact of bars, *Proc. Soc. exp. Stress Anal.* **12,** 2, 173–180, 1955.

This investigation has shown that the longitudinal impact of two elastic bars produces a wave of constant strain plus a rapid strain fluctuation whose period is approximately the time which would be required for a longitudinal wave to traverse the bar diameter. Measurements of the strain wave are made with wire-resistance gages and oscillographic recording apparatus. The observed fluctuation is somewhat greater than actual strain variation as a result of an induced signal voltage; this effect is attributable to magnetostriction. The characteristic strain fluctuation can be modified by the interposition of padding material such as grease or solder between colliding surfaces. A slightly conical nose on one of the colliding bars is also beneficial. The magnetostrictive distortion can be reduced by careful demagnetization of the bar, selective connection of gage elements, or by use of nonmagnetostrictive bar material.

From author's summary

2464. Berry, D. S., and Hunter, S. C., The propagation of dynamic stresses in visco-elastic rods, *J. Mech. Phys. Solids* **4,** 2, 72–95, Feb. 1956.

The propagation of stress waves in thin rods of materials which obey Boltzmann's superposition principle is treated by the use of Laplace transforms. A number of different boundary conditions at the ends of the rod are considered. Solutions are obtained for constant applied stress, constant rate of strain, and sinusoidal motion in both finite and semi-infinite rods of materials which behave like Maxwell, Voigt, or "standard linear" solids. The theory of some stress-propagation experiments which would determine the creep and stress-relaxation functions of a given material is discussed.

H. Kolsky, USA

2465. Greenspon, J. E., Stresses and deflections in flat rectangular plates under dynamic lateral loads based on linear theory, *Inter. Shipbldg. Progr.* **3,** 18, 63–76, Feb. 1956.

2466. Eringen, A. C., Response of an elastic disk to impact and moving loads, *Quart. J. Mech. appl. Math.* **8,** 4, 385–393, Dec. 1955.

Theoretical solution of the title problem, using Fourier transforms, is given and special cases of moving loads, including normal and tangential stresses, impact load, concentrated load, and some of their combinations, are considered. Computation and discussion of results for the case of a concentrated load acting on a steel cylinder is carried out, and resonance speeds in multiples of surface wave velocity are given. Results, which have not yet been verified experimentally, are of special interest for the design of high-speed roller bearings.

V. Kopřiva, Czechoslovakia

2467. Mirsky, I., and Hermann, G., Axially-symmetric motions of thick shells, Columbia Univ., N.Y., Dept. Civ. Engng. & Engng. Mech. OSR-ARDC Tech. Note no. 2, 20 pp. + 1 fig., Nov. 1955.

An approximate theory of axially-symmetric motions of thick, elastic, cylindrical shells, in which the effect of transverse normal stress is retained, is deduced from the three-dimensional theory of elasticity. The present theory contains, as special cases, a variety of shell, plate, and solid cylinder equations.

The propagation of free harmonic waves in the shell is studied on the basis of the present theory and the three-dimensional theory of elasticity. Excellent agreement is obtained for the phase velocity of the lowest mode of motion for a wide range of the parameters involved.

From authors' summary by H. N. Abramson, USA

2468. Eason, G., and Shield, R. T., Dynamic loading of rigid-plastic cylindrical shells, *J. Mech. Phys. Solids* **4,** 2, 53–71, Feb. 1956.

The treatment is for axially symmetric loading and is restricted to small deformations. A ring of force or band of pressure is applied to the shell. In time the load is a rectangular or triangular pulse, or it moves along the shell at constant velocity. Analysis is by standard plastic-rigid theory, with an approximate yield condition. Solution is complete, within the assumptions made, and extensive numerical results are given by plots of reduced variables.

F. C. Roesler, England

2469. Radok, J. R. M., On the solution of problems of dynamic plane elasticity, *Aero. Res. Labs. Melbourne, Austral. Rep.* SM. 230, 16 pp., July 1955.

Author shows that the dynamic problem of plane elasticity requires finding a solution to a generalized biharmonic wave-type equation. Then, for a specialized type of moving disturbance, he obtains complex variable solutions of the Muskhelishvili type. He solves two problems previously solved by other means, (1) the moving Griffith crack and (2) moving dislocations, and shows that the solution of his equation is two analytic functions corresponding to the longitudinal and shear waves which occur in elastic media. S. F. Borg, USA

2470. Goldsmith, W., and Allen, W. A., Graphical representation of the spherical propagation of explosive pulses in elastic media, *J. acoust. Soc. Amer.* **27,** 1, 47–55, Jan. 1955.

The problem of spherically symmetric wave propagation in homogeneous, isotropic elastic media of infinite extent has been examined frequently in recent years, and a number of analytical solutions have been reported in the literature for various initial conditions. Some interest has also been exhibited in the application of these relations to the transient phenomena occurring in metals when subjected to contact explosions. Under these conditions, an actual wave system can be approximated by postulating the existence of a spherical cavity in the interior of the medium and applying as the initial condition a pulse of exponentially decaying character. While no difficulty is encountered here in an analytic expression of the displacements, velocities, and stresses occurring at each point of the medium as a function of location and time, it has been found highly desirable to represent these terms in pictorial form to permit a rapid evaluation of the nature of the disturbances in the region of interest. Consequently, numerical calculations have been performed on an IBM machine and the resultant data have been employed in a space-time representation of these parameters.

From authors' summary

Elasticity Theory

(See also Revs. 2432, 2451, 2463, 2469, 2486, 2495, 2501, 2505, 2767, 2778)

2471. Williams, M. L., Large deflection analysis for a plate strip subjected to normal pressure and heating, *J. appl. Mech.* **22,** 4, 458–460, Dec. 1955.

A large deflection analysis is carried out to determine the deflections and membrane stresses for an infinite plate strip when subjected to normal pressure and temperature variations across the width of the strip with the end points fixed in space. Results are graphed for clamped and simply supported edge conditions in the case of uniform temperature T_0 and uniform pressure p_0. The calculations also include the possible thermal buckling deflections. In the limit case of a membrane (width b, thickness h) with the same loading condition, the central deflection u_0 is determined from the simple relation

$$[(u_0/h)^2 - (3/8)(1+\nu)(b/h)^2 \alpha T_0](u_0/h) = p_0 b^4/(256\, Dh);\quad D = E(1-\nu^2)h^3/12$$

The governing equation is based on an energy approach in order to facilitate application to approximate solutions for related cases not included in this paper. It is a remarkable point that this equation changes type depending upon the magnitude of the middleplane (compressive) stress induced by the heating with respect to the (tension) stress caused by the pressure.

The results are concentrated in diagrams (see especially figs. 4 and 6). M. Schaefer, Germany

2472. Ogibalov, P. M., Effect of internal pressure and varying temperature on the deformation of pipes (in Russian), *Inzhener. Sbornik, Akad. Nauk SSSR* no. 20, 55–58, 1954.

Author deals with plane state of stress in a cylindrical tube with inner radius a, external radius b. He introduces polar coordinates r, θ, x (x is coordinate in the direction of the axis of the tube). The tube is symmetrically loaded and warmed in rotation [its temperature is $\vartheta(r)$]. Displacement (the state being plane) is characterized by a single function $w(r)$ – the radial displacement.

Then

$$\epsilon_r = dw/dr, \qquad \epsilon_\theta = w/r, \qquad \epsilon_x = \epsilon = \text{const} \tag{1}$$

According to Hooke's relation

$$\begin{aligned}
\epsilon_r &= 1/E[\sigma_r - (1/\nu)(\sigma_\theta + \sigma_x)] + \alpha\vartheta(r),\\
\epsilon_\theta &= 1/E[\sigma_\theta - (1/\nu)(\sigma_r + \sigma_x)] + \alpha\vartheta(r),\\
\epsilon_x &= 1/E[\sigma_x - (1/\nu)(\sigma_r + \sigma_\theta)] + \alpha\vartheta(r)
\end{aligned} \tag{2}$$

Author writes the equilibrium equation

$$(d\sigma_r/dr) + (\sigma_r - \sigma_\theta)/r = 0 \tag{3}$$

and, with help of [1], [2], [3], constructs differential equation

$$(d^2u/dr^2) + (1/r)(du/dr) - (w/r^2) = (\nu + 1/\nu - 1)\,\alpha(d\vartheta/dr) \tag{4}$$

for the function $w(r)$. He writes general solution of [4] and determines unknown constants, prescribing pressures $\sigma_r(a) = -p_a$; $\sigma_r(b) = -p_b$ on inner and external surface of the tube, respectively, and using condition of the plane state of stress $\int_a^b 2\pi r\sigma_x\, dr = 0$. Then he intends to determine the temperature $\vartheta(r)$ in such a manner that for all $r(a \leq r \leq b)$ would hold

$$\tau_{max} = \sigma_s/3^{1/2} \tag{5}$$

where $\tau_{max}(r)$ is the maximum shear stress and σ_s the elastic limit of material of the tube. This problem leads to an integral equation, solution of which, if $(a) = \vartheta_a$, is

$$\vartheta = \vartheta_a - [4(\nu - 1)\,\sigma_s/\nu E\alpha 3^{1/2}]\,\lg\,(r/a) \tag{6}$$

Author then shows that, when $\vartheta(r)$ is given by [6], the water pressure p_r can be chosen much greater (without passing the elastic limit) than in the case of an unwarmed tube.

An interesting problem! K. Rektorys, Czechoslovakia

2473. **Lansard, R., Fillets without stress concentration,** *Proc. Soc. Exp. Stress Anal.* **13**, 1, 97–104, 1955.

In a circular fillet, however large the radius is, there is always a stress concentration. It is possible to design progressive curvature fillets, in which stress is constant along the profile, so that there is no more chance of failure in the fillet than anywhere else. This paper gives the profile of such fillets in the case of plates in tension or bending. From author's summary

2474. **Jaeger, H. E., Burghgraef, B., and Van Der Ham, I., Investigation of the stress distribution in corrugated bulkheads with vertical troughs,** *Inter. Shipbldg. Progr.* **2**, 1, 3–29, 1955.

This report deals with the stress distribution in a transverse corrugated bulkhead with vertical troughs. Its aim is to arrive at a method of calculation suited for use in practice. A method, based on elementary principles, and the necessary assumptions are discussed and an example is given. The problem of local instability is discussed and the stresses in the welds of the plating are considered. The effect of the adoption of corrugated bulkheads on weight is discussed briefly.

Some tests on a corrugated bulkhead are described and a comparison is made between the calculated and measured stresses. It is shown that there is a reasonable agreement, which, in the opinion of the authors, justifies the method of calculation discussed.

The desirability of more extensive stress measurements on a bulkhead of this type is mentioned. From authors' summary

Experimental Stress Analysis

(See Rev. 2763)

Rods, Beams, Cables, Machine Elements

(See also Revs. 2451, 2488, 2519)

2475. **Sahmel, P., Optimum forms of torsionally loaded I or [beams** (in German), *Bauingenieur* **30**, 11, 403–404, Nov. 1955.

For beams with only one axis of symmetry, author derives the formula for the coordinate of the center of shear as a function of the geometrical parameters. J. W. Cohen, Holland

2476. **Bisgaard, J. J., Determination of stresses in a circular cylindrical reinforced concrete column, eccentrically compressed** (in Danish), *Bygnsstat. Medd.* **26**, 1, 23–32, Aug. 1955.

Calculation is based on the usual assumption of linearly distributed stresses, a constant ratio E_s/E_c, and zero tensile strength of concrete. Formulas are developed and a diagram is shown which yields the relation between eccentricity, percentage of reinforcement, and stresses.

S. E. Kindem, Norway

2477. **Hu, L.-S., Eccentric bending in two directions of rectangular concrete columns,** *J. Amer. Concr. Inst.* **26**, 9, 921–936, May 1955.

Title problem is investigated assuming that the slope of the neutral axis is the same as that for a homogeneous section. Charts and numerical examples have been given. If the sections are rectangular, the errors made in using these charts are negligible.

Y. V. G. Acharya, India

2478. **Szombathy, E., Design of dove tails** (in Hungarian), *Mérés és Automatika* **3**, 11, 333–338, Nov. 1955.

2479. **Wuest, W., Calculation of Bourdon springs used for measurement of high pressure** (in German), *ZVDI* **97**, 35, 1277–1278, Dec. 1955.

2480. **Starzhinskiĭ, V. M., Stability of flexible shafts with nonsymmetric spacing of pulleys** (in Russian), *Inzhener. Shornik, Akad. Nauk SSR* no. 20, 31–36, 1954.

2481. **Ōkubo, H., Form number of twisted shafts with several notches** (in German), *Ing.-Arch.* **23**, 2, 130–132, 1955.

An approximate solution is obtained for the torsion problem of a circular shaft with several notches. From exact solution [H. Ōkubo, *J. appl. Mech.* **17**, p. 359, 1950; AMR **3**, Rev. 1968], the approximate solution is derived for infinite shafts with small, nearly semicircular notches. This solution is compared with one obtained by Neuber, and an essential difference is found. Then a practical approximate solution is obtained for finite shafts with several small notches. Its usefulness is satisfactorily proved through comparison with exact results.

H. Fernández Long, Argentina

2482. **Tolokonnikov, L. A., Sections with finite symmetrical deformations** (in Russian), *Prikl. Mat. Mekh.* **18**, 5, 619–626, Sept.-Oct. 1954.

Bending stresses and deformations of curved bars are analyzed with standard simplifying assumptions. The differential equations are developed, with the only variables being tangential and radial stresses and elongations, assuming no axial deformations, and for the general case with axial elongations. For the special case of a thin curved plate with hypothetical assumption that $\sigma_r = E(1 + \epsilon_r)(\epsilon_r + 1/2\epsilon_t)$ and $\sigma_t = E(1 + \epsilon_t)(\epsilon_t + 1/2\epsilon_r)$, formulas for radial and tangential stresses are developed as $f[(r/\rho_0)(\rho_0/\rho)]$ where r is given radius of curvature, ρ_0 radius of curvature of neutral surface before stress, ρ in stressed status, plus certain constants.

From these general formulas, magnitudes of special cases of curved bar stress-strain relations can be solved; only the determination of constants and complexity of the formula make solving difficult. This very condensed treatise loses a great deal of its value due to a very large number of proof-reading errors which force the checking of everything before use. A. L. Nasvytis, USA

2483. **Vidéky, E., Kinematic and geometrical calculations on involute spur gears,** *Acta Techn. Hung. Budapest* **9**, 3/4, 277–303, 1954.

Expository paper on involutometry of spur and helical gearing operating on pitch circles other than those of generation; author deals with corrected gears without backlash, gears with several mates, all addendum gears, etc. Results are commonly known [Merritt, "Gears," 1942; Buckingham, "Spur gears," 1928; "Manual of gear design," 1935; "Analytical mechanics of gears," 1949]. Author states "The module may be generally chosen with no regard to strength [5]; even the surface stress, which increases somewhat at a smaller module (worst curvature of the profile), is amply compensated by the increased contact ratio at greater numbers of teeth." First part is not true for case-hardened and short-life high-rated gears; second part is true in result but relative curvature is, in fact, unaffected by module for given base circles. Author also states "With a worm hob, the involute developed in the gear plane is only an approximate involute, the more distorted, the greater is the spiral angle." This appears to refer to a hob straight sited on the axial section since, with an involute helicoid hob, true involutes are generated.

Reviewer was surprised to find substantial claims for priority, notably analysis of undercutting and interference (1906), application of Hertz contact stress theory to gear rating (1908), and introduction of involute function. Author's name was unknown to reviewer who was apparently in good company as it does not occur in any of the standard authorities—U.S., U.K., German, or French. First claim appears unwarranted [see, e.g., Grant's "Handbook on the teeth of gear," Boston, 1887; Mansfield, *J. Franklin Inst.* 1877], but author did certainly apply Hertzian theory in 1908 two years before Logue's proposal to use relative curvature as basis of rating [*Z. Öst. Ing.-Arch. Ver.* **70**, 579; Amer. Machinists Gear Book, 1910]. No date is given for introduction of involute function, generally, credited to Buckingham ["Spur gear," 1928]. Clearly, author's work has been insufficiently noted.

E. M'Ewen, England

2484. **Hansen, F., The calculation of plane pile group with elastic superstructure** (in Danish), *Bygnsstat. Medd.* **27**, 1, 9–20, Feb. 1956.

Author develops a method for computation of the forces in a plane pile group with an elastic superstructure by combining the formulas valid for a rigid superstructure with those for a beam on elastic supports. From author's summary by K. J. Sundquist, Sweden

2485. **Rhodes, A. F., and Wilhoit, J. C., Jr., Oil and gaswell casing suspension assemblies,** *Trans. ASME* **78**, 2, 225–232, Feb. 1956.

Reviewer believes this is one of the most intelligent studies reported recently. It warrants reading not only for its specific contents, but also as an example to be emulated.

The deformations and stresses in the subject equipment are developed theoretically, using the theory of a beam on an elastic foundation. Two relatively simple solutions are used to bracket the range of values in the actual case. The accuracy of the results are checked by experiments using strain gages.

From the results of the theoretical analysis and experimental study, criteria of performance are proposed and discussed within the framework of the physical limitations of the actual problem. From the nature of the factors affecting the design, attention is directed to the one which is both fruitful and attainable; and a specific improvement therein is suggested. E. J. McBride, USA

Plates, Disks, Shells, Membranes

(See also Revs. 2448, 2450, 2465, 2468, 2481, 2506, 2518, 2525)

2486. Stippes, M., A note on the simply-supported plate, *Quart. appl. Math.* **14,** 1, 90-93, Apr. 1956.

Author shows that the bending moments and shears in a rectangular plate with a concentrated load at an interior point can be expressed in a closed form in the sense of being in terms of Weierstrassian elliptic functions and their derivatives. B. E. Gatewood, USA

2487. El-Hashimy, M. M., Selected plate problems (in German), *Mitt. Inst. Baustat., ETH Zürich,* no 29, 96 pp., 1956.

Author presents a short but interesting monograph on the bending of thin flat plates defined by the usual Lagrangian plate equation. The work is divided into four parts of approximately equal length.

In the first part is given the analysis of a circular plate with an eccentric circular hole. Both inner and outer edges are assumed clamped and the load is a uniformly distributed pressure. The complete development is given in bipolar coordinates, along with details of a numerical example.

The second quarter of the work is devoted to the theory of singular points and eccentric concentrated loads on a circular plate. A considerable number of plotted curves derived for use with the notion of influence lines and surfaces are given.

Next, a rectangular plate with a centrally located circular hole is studied. A special examination is made of the effect of small holes. Various boundary conditions, including the clamped all around, are introduced. Numerical solutions are given.

The last part of the monograph is given to the study of rectangular plates with slits along a center line. The analysis covers various loads and boundary conditions. W. H. Hoppmann, II, USA

2488. Ordway, D. E., and Riparbelli, C., An application of the method of equivalence to the deflection of a triangular plate, *J. aero. Sci.* **23,** 3, 252-258, Mar. 1956.

Approximate method is described for calculating deflections of thin delta plates. Plate is divided into a number of thin chordwise strips. Deformations of strips are then computed by elementary theory, assuming no chordwise bending and no restraint of warping. Approximate correction is then made for chordwise bending by accounting for the residual loads introduced by the rigid-chord assumption. Comparisons are made with experiment; agreement is fair.

J. M. Hedgepeth, USA

2489. Riparbelli, C., Oblique bending of a trapezoidal plate, *Cornell aero. Lab. Rep.* OSR-TN-56-9, 6 pp. + 2 figs., Nov. 1955.

In this paper author extends his previous investigation [see preceding review] to trapezoidal plates. Curves are presented showing the relation of α to β for plate angles up to two radians where the plate angle is defined as the angle formed at the intersection of the extrusion of the edges of the plate. The formula for the maximum curvature is also presented. K. Arnstein, USA

2490. Constantinescu-Catunesti, S., Oblique plates. A method of numerical calculation (in Rumanian), *Acad. Repub. pop. Române Comun.* **5,** 6, 913-922, 1955.

Author calculates deflection of simply supported parallelepiped plate by replacing biharmonic equation with two harmonic equations. These are expressed in finite difference form and numerical solution is carried through by relaxation procedure. Author apparently regards as major contribution his expressing the Laplacian for oblique coordinates in finite difference form. G. W. Housner, USA

2491. Oseled'ko, A. I., Bending of trapezoidal plates (in Russian), *Inzhener. Sbornik, Akad. Nauk SSSR* **21,** 142-150, 1955.

Author considers a thin plate, clamped along all edges and subjected to a uniformly distributed loading. Deflections are calculated using two different energy methods and compared with experiments using plexiglass. The discrepancies appear to be quite large.

G. Herrmann, USA

2492. Hoppmann, W. H., II, New apparatus for study of deformation of clamped circular plate loaded with lateral pressure, *Proc. Soc. exp. Stress Anal.* **12,** 2, 201-206, 1955.

Clamping of circular plates loaded with lateral pressure by means of bolts is never uniform. New apparatus is described which avoids use of bolts. Clamping is obtained by use of a level device through centering head. Tests made on aluminum plates are reported in elastic range; complete agreement is found with linear theory. For these plates, (0.033 inch) agreement in the plastic range with the Way theory is perfect. For thicker plates, slip causes lack of agreement.

W. Soete, Belgium

2493. Sonntag, G., Influence of a displacement of the edges for uniformly loaded membranes or thin plates with large deflection (in German). *Forsch. Geb. Ing.-Wes.* **22,** 1, 21-26, 1956.

The effect of edge-displacements on the deflection as well as on the stresses of circular and quadratic plates can be expressed by simple (approximative) formulas. No important changes in the deflection or in the membrane stresses of a thin plate occur if the clamping of the edge about *its tangent* is made an elastic one. On the other hand, important changes in the deflection occur on releasing the clamping *in the plane* of the plate (or the membrane). Unallowable tangential stresses may, in that case, arise in curcular plates.

From author's summary by C. B. Biezeno, Holland

2494. Reissner, E., Stresses in elastic plates over flexible subgrades, *Proc. Amer. Soc. civ. Engrs.* **81,** Separ. no. 690, 29 pp., May 1955.

Comparative studies are made on four different types of flexible subgrades to determine the adequacy of existing relationship. These are: (1) Infinite elastic plate carrying a load distributed uniformly over a finite circular area; (2) infinite elastic plate carrying a load distributed parabolically over a finite circular area; (3) infinite elastic plate subjected to uniform tension in plane of plate and carrying uniformly distributed lateral load; and (4) nonlinear effects. The analysis of the problems is based on the representation of the subgrade by a system of springs or by a heavy liquid. Simple approximate formulas are obtained for the maximum tension stress in the surface layer and for maximum deflection of surface layer for load distributed uniformly in circular areas. It is shown that, as long as the ratio of the diameter of load surface to thickness of surface layer is about unity or larger, it is permissible to consider surface layer as a thin plate. When this ratio lies between one and two, transverse shear deformation in plate becomes significant. S. K. Ghaswala, India

2495. Hodge, P. G., Jr., Stress functions for rotating plates, *J. appl. Mech.* **23,** 2, 273-276, June 1956.

Author considers problem of determining the elastic stresses in a thin plate of uniform thickness with essentially arbitrary edge shape, rotating with uniform angular velocity about an axis in its plane. Assuming a plane stress distribution, the problem reduces to the solution of a nonhomogeneous biharmonic equation with boundary conditions of vanishing stress on such portions of the plate edge as do not coincide with the axis of revolution. Boundary conditions are not satisfied on the latter, Saint-Venant's principle being invoked to justify solution save near this axis. Case (a) is solved exactly. In case (b) the displacement conditions (see above) on the axis of revolution are not satisfied. Results for this case are shown to reduce to

those obtained by the use of beam theory in another paper of author [MR 9, Rev. 1410].

W. H. Pell, USA

2496. Youngquist, W. G., and Kuenzi, E. W., Stresses induced in a sandwich panel by load applied at an insert, (Suppl. no. 2) *For. Prod. Lab. Rep., U. S. Dept. Agric.* no. 1845-B, 4 pp. + 4 tables + 3 figs., Feb. 1956.

Previously published formulas for stresses in sandwich panels loaded through a central insert were known to be valid for loads normal to the panel faces on the basis of the experimental evidence available. Additional test data indicate that the formulas can also be used, if properly modified, whenever the load is applied at other angles to the insert. The observed strains in the panel faces were found to be directly proportioned to the magnitude of the normal component of the applied load.

E. G. Stern, USA

2497. Huffington, N. J., Jr., Theoretical determination of rigidity properties of orthogonally stiffened plates, J. appl. Mech. **23**, 1, 15-20, Mar. 1956

The four elastic rigidity constants of a thin orthotropic plate, denoted by D_x, D_y(bending), D_{xy}(twisting) and $D_1 = \nu_{xy}.D_y = \nu_{yx}D_x$, (where ν_{xy} and ν_{yx} are the two Poisson ratios), are determined for a plate with equally spaced stiffeners of rectangular cross section, disposed symmetrically with respect to the middle plane of the plate.

The x-coordinate direction is taken to be parallel to the stiffeners. The deflection function w of an infinitely long strip of the equivalent orthotropic plate, having simply supported boundaries parallel to the y-direction (normal to x) and loaded by a uniform pressure p_o, is dependent only on the elastic parameter D_x. In the analysis of the actual stiffened plate, this composite structure is considered as made up of a series of plates, separated by beams of rectangular cross section. By determining the strain energies of bending and twisting stored in one repeating section of the actual and equivalent orthotropic plates, and by taking equivalence of strain energies as the equivalence criterion, one obtains a rather complicated expression for D_x. If the width of the strip is increased from zero, D_x rapidly approaches an asymptotic value which can easily be obtained by treating the stiffened plate as a wide beam.

In the same manner, with supported boundaries in the x-direction, D_y is determined, while for the determination of D_{xy} the plates are loaded by twisting moments. D_1 is determined by employing another criterion, namely, the equality of bending moments for the direction normal to the plane of maximum curvature.

The comparison of the theoretically determined constants D_x, D_y, and D_{xy} with experimental data shows a satisfactory agreement.

The formulas of the rigidity constants developed in this paper will be useful when the ratios of plate widths to stiffener spacing are not large enough to justify use of the limiting values. The numerical evaluation of these formulas is rather wearisome. Therefore, diagrams are desirable showing how rapidly the asymptotic limiting values are reached.

E. Seydel, Germany

2498. Raville, M. E., Deflection and stresses in a uniformly loaded, simply supported, rectangular sandwich plate, *For. Prod. Lab. Rep., U. S. Dept. Agric. Rep.* no. 1847, 35 pp. + 1 table + 16 figs., Dec. 1955.

Based on usual assumptions of sandwich constructions, the solutions for the deflections and stresses of a uniformly loaded, simply supported, rectangular plate have been obtained. They are expressed in the form of slowly convergent double Fourier series. However, these solutions are applicable to any sandwich plate having an orthotropic core and isotropic facings of equal and unequal thickness, provided that both thicknesses are relatively small in comparison with the core thickness. Tabulated solutions and curves are given for various cases.

A more general expression for the solution of the problem is also presented to include considerations of the flexural stiffness of the individual facings and a finite value of the modulus of elasticity of the core in the transverse direction.

T. T. Loo, USA

2499. Brown, L. W., An experimental investigation into some of the problems associated with stress diffusion in the vicinity of chordwise cut-outs in the wing, and a comparison with existing theories, *Coll. Aero. Cranfield Rep.* no. 83, 29 pp. + 27 figs., Sept. 1954.

2500. McComb, H. G., Jr., and Low, E. F., Jr., Comparison between theoretical and experimental stresses in circular semimonocoque cylinders with rectangular cutouts, *NACA TN* 3544, 20 pp., Oct. 1955.

Comparisons are made between a theory for calculating stresses about rectangular cutouts in circular cylinders of semimonocoque construction published in *NACA TN* 3200 and previously published experimental data. The comparisons include stresses in the stringers and shear stresses in the center of the shear panels in the neighborhood of the cutout. The theory takes into account the bending flexibility of the rings in the structure, and this factor is found to be important in the calculation of stresses about cutouts. In general, when the ring flexibility is considered, good agreement is obtained between the calculated and experimental results.

From authors' summary by M. C. Steele, USA

2501. Kempner, J., and Crouzet-Pascal, J., Postbuckling behavior of circular cylindrical shells under hydrostatic pressure, *Polyt. Inst. Brooklyn, Aero. Lab. Rep.* no. 343, 33 pp. + 10 figs., Jan. 1956.

The postbuckling behavior of initially perfect, thin-walled circular cylindrical shells under hydrostatic pressure is investigated analytically with the aid of the principle of stationary potential energy together with plausible deflection functions. The results obtained indicate that postbuckling equilibrium configurations exist for loads greater than, as well as loads slightly less than, the critical load as calculated by use of Love's classical small-deflection theory. Loads less than the critical load are obtained only for certain values of a parameter considered indicative of the shell geometry. For deflections of the order of magnitude of the shell thickness it was found that the number of circumferential waves remains essentially constant with increasing deflection and equal to the number of waves developed at the instant of buckling. The minimum value of the postbuckling load was found to be only 3% less than the critical load predicted by linear theory, whereas experimental collapse pressures are as small as 60% of the theoretical pressure.

Reviewer agrees with author in believing that better agreement with experiment might be obtained by considering initial imperfections of the shell.

W. A. Nash, USA

2502. Hoff, N. J., Thin circular conical shells under arbitrary loads, *J. appl. Mech.* **22**, 4, 557-562, Dec. 1955.

Employing approximations that are seemingly legitimate for cones with moderately small vertex angles, author develops simplified formulas for membrane strains and incremental curvatures of a conical shell in terms of the displacement vector of the middle surface. Linear geometric approximations of small displacement theory are used. Principle of stationary potential energy provides differential equations of equilibrium and natural boundary conditions in terms of displacements of middle surface. Differentiation and algebraic manipulation lead to a differential equation in which the normal displacement component w is separated from the tangential components u, v. Also, in the remaining equations, u and v are separated from each other. Author considers a class of solutions of the w equation in the form $w = f(x) \sin p\phi$, and discusses power series solution of the differential equation for $f(x)$.

H. L. Langhaar, USA

2503. Chronowicz, A., Simplified solution of the differential equation of cylindrical shells. Parts 1, 2, 3, *Civ. Engng., Lond.* **50**: 586, 397-400, Apr. 1955; 587, 539-541, May, 1955; 588, 664-666, June 1955.

Finsterwalder's equation is used for evaluating stresses in cylindrical shells. Simultaneous equations of equilibrium at the edge are solved directly for constants as unknowns. Evaluation of constants according to this method reduces the amount of tedious calculation. Paper is written for students and beginners. Numerical examples are given.

H. Fernández Long, Argentina

2504. Fessler, H., and Lewin, B. H., Stress distribution in a tee junction of thick pipes, *Brit. J. appl. Phys.* **7**, 2, 76-79, Feb. 1956.

The stress distribution on the inner surfaces of both pipes near their juncture, as caused by internal pressure, was determined by the "frozen stress" photoelastic technique. An approximate method of calculation (based on the theoretical solution for a hole in an infinite plate under uniform tension) was developed and a measure of agreement (38% error) between the calculated and measured stresses was found. No details of

the photoelastic test are presented, while the very approximate "theoretical solution" is presented in laborious detail. Reviewer would be more interested in stress distribution on the outer pipe surfaces in vicinity of juncture. M. M. Leven, USA

2505. Charbonnier, J., Study of resistance of shrink-fit tubes in the elastic range (in French), *Mém. Artill. fr.* **29**, 2, 347–378, 1955.

As author mentions in his résumé, no new results are presented in this paper on shrink-fitted tubes, which is essentially restricted to the elastic domain, the limits of which are prescribed by the Coulomb-Guest shear hypothesis. Within these limits the reader will find, illustrated by many practical graphs the answer to all questions which may interest the actual designer. C. B. Biezeno, Holland

Buckling Problems

(See also Revs. 2447, 2477)

2506. Haft, E. E., Elastic stability of cylindrical sandwich shells under axial and lateral load, *For. Prod. Lab. Rep., U.S. Dept. Agric. Rep. no.* 1852, 33 pp., July 1955.

A double sine-wave type of displacement throughout core and faces of the sandwich cylinder is imposed, and displacements are made consistent at junctions between core and faces. Conditions of equilibrium at these junctions lead to a determinantal equation governing critical combinations of uniform end-load and external pressure. Curves are plotted of solutions for the two cases (a) end-load only, (b) external pressure on cylindrical surface together with end-load due to equal pressure on circular ends.

It is surprising that no mention is made of the possibility of the occurrence of the inward diamond-shape buckle commonly associated with cylindrical shells. The functional notation used is both confused and confusing and the presentation is by no means clear. Fig. 4 is in error. K. H. Griffin, England

2507. Roik, K., Torsion-flexural buckling of centrally compressed columns with open cross section in the nonelastic regime. Parts I, II (in German), *Stahlbau* **25**: 1, 10–17, Jan. 1956; 2, 32–35, Feb. 1956.

Author considers buckling of short columns of I-section for which buckling stress is beyond elastic limit. He determines buckling load for Karman-type buckling and for Shanley tangent modulus buckling, and compares with German Building Code formula. Formula is found to be in close agreement with Karman-type buckling and to be somewhat larger than Shanley-type buckling. G. W. Housner, USA

2508. Penovko, Ya. G., Critical force of compressed columns in the inelastic range (in Russian), *Inzhener. Sbornik, Akad. Nauk SSSR* no. 20, 160–163, 1954.

Paper establishes the previously well-known fact that maximum load of inelastic columns lies between tangent modulus (Shanley) and reduced modulus (Karman) loads, in view of the fact that beyond P_t with increasing load and deflection E_t decreases. It appears that in 1951 I. N. Rabotnov reproved the Shanley derivation by using a model entirely identical with Shanley's except that the column model is fixed-free instead of hinged-hinged. Author uses that same model to establish that maximum load lies between indicated limits.

G. Winter, USA

2509. Hult, J., Creep buckling, *Instn. Hållfasthetslära Publ.* no. 111, 36 pp., 1955.

Some general creep laws are studied from the point of view of time variable stress. Conditions are formulated which must be fulfilled if the stress-load relation is to be constant. Creep design criteria are discussed. A previous creep-buckling theory by Hoff [AMR **7**, Rev. 2444] and Odqvist [AMR **8**, Rev. 1002], which concerned nonlinear creep buckling of idealized equally flanged H-sections, is generalized to unequally flanged H-sections and a formula for the critical buckling time is given.

Experiments on pure-aluminum H-section columns are reported. The test results confirm the general theory and also show that even for nonlinear creep buckling the deflection curve is almost a pure sine.

From author's summary by W. T. Koiter, Holland

2510. Benthem, J. P., On the buckling of bars and plates in the plastic range, Part II, *NACA TN* 1392, 79 pp., Mar. 1956.

See AMR **8**, Rev. 3375.

Structures

(See also Revs. 2431, 2476, 2484, 2496, 2506, 2527, 2530, 2540, 2768, 2770)

Book—2511. Chamecki, S., Course in structural statics [*Curso de Estática das Construções*], Rio de Janeiro, Editora Cientifica, 1956, 241 pp.

This first volume presents very simply the general theory of linear, plane and three-dimensional structures, with practical applications demonstrated in a series of examples. Theoretical discussions are accompanied by pictures of spectacular structures built centuries ago up to the present, with interesting examples of modern space structures. Author gives full credit to the founders of various basic theories in structural design and inserts their photographs (Leonardo da Vinci, Euler, Coulomb, Navier, Saint-Venant, Rankine, Culmann, Mohr, Föppl). Principles of isostatic, hyper- and hypostatic structures are thoroughly discussed, and structural safety is emphasized and exemplified by notable failures (Tacoma bridge and others). Graphical methods are applied only to statically determinate structures. For statically indeterminate structures only, methods of virtual work and of displacements are used. Last chapter is devoted to probability of failures.

Series of tables simplify calculations. References are made to many publications in the field (Rocha, Stüssi, Saliger, van den Broock, Torroja, Timoshenko, Baes, Hetényi, and others).

J. J. Polivka, USA

2512. Kasarnowsky, S., Calculation of stresses of two parallel arches stayed by wind braces (in Swedish). *IngenVetenskAkad. Tidsk. Tekn. Forsk.* **27**, 1, 31–42, 1956.

Moments in various types of arches due to lateral wind are investigated. Formulas for maximum moment are given for concentrated load at center of span, uniform load over entire span, and uniform load over half span. A. Selberg, Norway

2513. Franciosi, V., Flexural lateral instability of two arches connected laterally (in Italian), *Ingegnere* **28**, 7, 727–736, July 1954

2514. Pyka, A. J., Influence lines for reactions of continuous trusses, *Proc. Amer. Soc. civ. Engrs.* **82**, ST 2 (*J. Struct. Div.*) Pap. 914, 16 pp., Mar. 1956.

2515. Hodge, P. G., Jr., and Venkatraman, B., Analysis of frameworks in the presence of steady creep, *Polyt. Inst. Brooklyn, Aero. Lab. Rep.* no. 333, 27 pp. + 5 figs., Nov. 1955.

Attack to problem is made through Hoff's analogy between stress distribution in a nonlinear elastic structure and a structure whose material deforms only in steady creep. Solution is limited to two-dimensional frameworks subject to arbitrary forces. In addition to Hoff's analogy, approximation methods based on either the principle of minimum potential energy or on the principle of minimum complementary energy are developed and illustrated by three worked out examples. Results are compared to exact method and show that minimum potential energy method is best, but the error in calculation of displacements becomes of the order of 10% as the framework becomes even slightly complex.

No creep problems are solved, but a simple integration of the displacement values is indicated to obtain the creep strain as a function of time. Method is dependent on knowledge of plastic collapse analysis. No buckling is considered, and is believed by reviewer to be a serious limitation on method. T. A. Hunter, USA

2516. Allas, E. E., Effectiveness of concrete screens (in Russian), *Gidrotekh. Stroit.* **24**, 8, 21–23, 1955.

Critical analysis is made of the relative effectiveness of concrete wall screens sunk upstream of dams and other hydraulic structural foundations on more or less fissured strata. The purpose is to reduce

infiltration and prevent upheaving pressure buildup while avoiding excessive seepage through the supporting formations.

The study shows that, when the relative permeability and extension of the various rock formations is known, the economical choice can be computed between the use of said wall screens and the application of foundation drainage downstream to reduce the undersole infiltration pressures. Terms allowing for the residual permeability of the wall screens are emphasized.

Reviewer feels that, in cases different from the extremely simplified examples treated here, any number of combinations of the two systems may lead to the most economical and stable solution, all being predicated on the thorough survey of the properties of the underlying soil formations. B. Posniak, USA

2517. Lee, D., Prestressed concrete bridges, *J. Instn. Engrs., India* **35,** 7, 627–654, Aug. 1955.

2518. Rowe, P. W., A theoretical and experimental analysis of sheet-pile walls, *Proc. Instn. civ. Engrs.* **4,** 1, 32–69, Jan. 1955.

Variation of the maximum bending moment on sheet-pile walls with pile flexibility and soil stiffness is calculated for the cases of cantilevered piling and anchored piling, assuming a modulus of subgrade reaction which increases linearly with depth. The mathematics is too involved for direct design office use, but a final "master" moment/flexibility curve is calculated which is of universal application.

The value of the modulus of the soil is estimated from theory and simple stiff-wall tests, and results in good agreement between the theory and observations on model sheet-pile walls. The influence of seepage forces and more compressible subsoils than loose sand on the stability of sheet-piling is then readily estimated from observations of their influence on the soil modulus.

From author's summary

2519. Paduart, A., Breaking strength of prestressed concrete (in French), *Ann. Trav. publics Belg.* no. 1, 7–29, 1955.

Author considers failure stresses of prestressed concrete beams. Principal stresses and their directions are determined for several loading conditions and cross sections. Charts are included.

J. Michalos, USA

2520. Solvey, J., Bibliography and summaries of sandwich constructions (1939–1954), *Aero. Res. Lab. Melbourne, Austral.* ARL/SM 2, 86 pp., Oct. 1955.

2521. Williams, D., Pressure cabin design. A discussion of some of the structural problems involved, with suggestions for their solution, *Aero. Res. Counc. Lond. curr. Pap.* no. 226, 51 pp., Mar. 1955.

Rheology (Plastic, Viscoplastic Flow)

(See also Revs. 2432, 2449, 2464, 2509, 2510, 2786)

2522. Marin, J., and Hu, L. W., Biaxial plastic stress-strain relations of a mild steel for variable stress ratios, *Trans. ASME* **78,** 3, 499–509, Apr. 1956.

Results of several tests of thin tubes under combined tension and pressure are presented. Both constant and variable stress ratios are considered, also both loading and unloading. Results are compared with simple (isotropic) flow theory and, qualitatively, with slip theory.

Authors conclude: "(1) Plastic stress-strain relations for various types of variable biaxial stress-ratio conditions are in fair agreement with values predicted by the simple flow theory; (2) the distortion-energy criterion used in the simple flow theory is not verified by the test results; (3) for certain variable stress-loading paths, the slip theory is in better agreement than the simple flow theory; (4) Existing concepts of loading surfaces, as used in theories of plasticity, are not in agreement with the test results." P. G. Hodge, Jr., USA

2523. Mandel, J., On linear viscoelastic bodies (in French), *C. R. Acad. Sci. Paris* **241,** 25, 1910–1912, Dec. 1955.

In short note, author applies Laplace transform to the memory function representation of the viscoelastic stress-strain law and obtains equations analogous to those deducible from classical elasticity. Author does not seem to realize that the analogous elastic problem is dynamic, not static. D. R. Bland, England

2524. Lequear, H. A., and Lubahn, J. D., Certain departures from plastic ideality at small strains, ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55-A-151, 15 pp. + 27 figs.

From room temperature tests of OFHC copper involving strains up to about 1%, authors show that the results of creep tests and tensile tests can be related, within certain limitations, in terms of the rate sensitivity. They describe four different kinds of limitations or departures from plastic ideality (the concept that plastic deformation depends only on the current conditions and not on the past history).

M. J. Manjoine, USA

2525. Hodge, P. G., Jr., and Romano, F., Deformation of an elastic-plastic cylindrical shell with linear strain hardening, *Polyt. Inst. Brooklyn, Aero. Lab. Rep.* no. 299, 31 pp. + 7 figs., Sept. 1955.

A thin-walled circular cylindrical shell of finite length is subjected to slowly increasing uniform external pressure. The stress-strain curve for the material is assumed to consist of two straight line segments, one representing elastic behavior and the other linear strain hardening. Equations are set up for obtaining hoop stresses and bending moments in the shell using assumptions of isotropic strain hardening, a piecewise linear yield function between stress resultants, and flow-type stress-strain law.

Particular problem of cylinder with end rings is solved and results shown graphically. Solution is compared with more approximate results obtained by assuming material rigid before yield, perfectly plastic after yield, or both. S. B. Batdorf, USA

2526. Hodge, P. G., Jr., Minimum principles of piecewise linear isotropic plasticity, *Polyt. Inst. Brooklyn, Aero. Lab. Rep.* no. 298, 32 pp. + 3 figs., Aug. 1955.

The yield function is considered to be a combination of linear functions, with isotropic strain hardening. The properties at the intersection of two linear "segments" are analyzed in terms of a "slice" near the corner that shrinks to zero as the corner is approached. The flow law is then integrated piecewise, including the flow properties derived for the corners. Minimum energy principles are then applied to establish upper and lower total energy limits.

The assumptions do not permit direct applications to any real materials. The results do allow a closer approach to some plasticity problems, particularly for materials with reasonably linear, isotropic strain hardening, when the problem is handled by an experienced plastician who appreciates the limitations. H. I. Fusfeld, USA

2527. Prager, W., General theory of limiting states of equilibrium (in French), *J. Math. pures appl.* **34,** 4, 395–406, 1955.

This essay is an excellent introduction for the engineer to the design of structures and earthworks by limit analysis, a branch of plasticity theory. Author gives the main theorems, two examples, and ample references to the original papers. D. R. Bland, England

Failure, Mechanics of Solid State

(See also Revs. 2469, 2772, 2794)

2528. Dirkes, W. E., A method of predicting the effects of notches in uniaxial fatigue, *Trans. ASME* **78,** 3, 511–515, Apr. 1956.

An empirical method is given for constructing a curve of limiting alternating stress component versus mean stress component for ductile materials. The following test results from notched specimens are required for application of the method: static tensile strength, fatigue strength for one condition wherein the mean component exceeds the alternating component. R. E. Peterson, USA

2529. Gunn, K., Effect of yielding on the fatigue properties of test pieces containing stress concentrations, *Aero. Quart.* **6,** 4, 277–294, Nov. 1955.

A rational theory is presented for a little understood aspect of fatigue: The behavior of notched specimens under action of fluctuating stress

containing a steady component. Method is developed for predicting fatigue properties of notched specimens from those of unnotched specimens, under these conditions.

Effect of yielding at base of notch is to lower local maximum stress while local range of stress is unchanged. Result is decrease in local mean stress. Since in unnotched specimens permissible range is known to increase with decreasing mean stress, it is assumed that decrease in local mean stress will have corresponding effect.

In analyzing variation of range of stress with mean stress it is assumed that local stress governs behavior in fatigue. Curve representing variation is then parallel to that for unnotched specimens, but reduced by some factor, until yielding begins. As yielding continues, the local mean stress, and therefore the range, remains almost constant, even for increasing over-all mean stress. This continues until over-all stress becomes large enough to cause general yielding, after which the range drops sharply to zero. The knee in the curve thus formed is a characteristic feature of this theory.

Summary of experimental results of other investigators shows that curves of range versus mean stress closely resemble theoretical curve in general form. Actual values are somewhat higher than theory when theoretical stress concentration factors are used. Better fit is obtained using fatigue strength reduction factors. Author discusses possible modifications of theory, and various uncertain factors.

Reviewer feels that his paper is a definite contribution to the study of fatigue. C. W. Richards, USA

2530. Kepert, J. L., and Payne, A. O., Interim report on fatigue characteristics of a typical metal wing, *NACA TM* 1397, 80 pp., Mar. 1956.

Constant amplitude fatigue tests of seventy-two P-51D "Mustang" wings are reported. The tests were performed by a vibrational loading system and by an hydraulic loading device for conditions with and without varying amounts of pre-load. The results indicate that: (a) The frequency of occurrence of fatigue at any one location is related to the range of the loads applied; (b) the rate of propagation of visible cracks is more or less constant for a large portion of the life of the specimen; (c) the fatigue strength of the structure is similar to that of notched material having a theoretical stress concentration factor of more than 3.0; (d) the frequency distribution of fatigue life is approximately logarithmic normal; (e) the relative increase in fatigue life for a given preload depends on the maximum load of the loading cycle only, while the optimum pre-load value is approximately 85% of the ultimate failing load; and (f) that normal design procedure will not permit the determination of local stress levels with sufficient accuracy to determine the fatigue strength of an element of a redundant structure.

From authors' summary

2531. Thompson, N., Wadsworth, N., and Louat, N., The origin of fatigue fracture in copper, *Phil. Mag.* (8) **1,** 2, 113–126, Feb. 1956.

Paper describes metallographic observations of the development of fatigue cracks in copper. The specimens (polycrystal and single crystals) were tested in push-pull at 1000 cps. It is shown that the fatigue crack starts in a slip band inside a single grain. An electropolishing technique shows changes in the character of the slip band after 5% of the life has expired. Cracks more than one grain long were present when half the life had expired. It is confirmed that the fatigue life can be increased by preventing access of oxygen to the surface. The bearing of these observations on the problem of the origin of a fatigue crack is discussed. From authors' summary

2532. Uzhik, G. V., Tensile strength of plastic metals in brittle fracturing (in Russian), *Vestnik Mash.* **35,** 6, 13–17, June 1955.

Causing a metal to fail by brittle fracture calls either for the elimination of slip deformation caused by tangential stresses in testing or by destroying the conventional relation between the tangential and axial stresses. The first can be achieved by polyaxial nonuniform loading produced by proper shaping of tensile test specimens; the latter by using a low temperature during tensile testing of conventional smooth specimens. While even the temperature of liquid hydrogen cannot develop brittle fracture in 18% Cr–8% Ni steel, bronzes, duralumin, etc., testing at −253 C produces brittle fracture in silicon, structural, 0.45%C (normalized), 0.40% C–1.0% Cr (normalized and tempered at 200 C) steels and in Armco iron. No relation whatever was found between the tensile strength of smooth specimens broken at −253 C and those tested at 20 C, but a good agreement was found between low temperature testing and the results obtained on notched specimens at 20 C. Strength at −253 C has no relation to the yield point of corresponding metals at room temperature. J. D. Gat, USA

2533. Hebrant, F., Louis, H., Soete, W., and Vinckier, A., Modes of rupture as a function of state of tension and of the temperature (in French), *Rev. Soudure* **11,** 3, 24 pp., 1955.

The authors aimed at a determination of biaxial states of stress in a low-carbon steel (0.13 C) at the instant of fracture within the range of low temperatures with a minimum temperature equal to −180 C. The investigation was done in connection with certain failures in welded steel bridges in which crosswise welded flat bars broke. Their best specimens consisted of steel plates having the shape of a rectangular cross which they could subject to gradually increasing tensile forces along the branches in perpendicular directions to each other in a specially designed testing machine. Some of the crosses had sharp reentrant corners, some were rounded off by fillets in the corners, a few were equipped with "crack-stoppers" by welding on the surface around the four sharp corners some additional, ductile steel reinforcements. Authors investigated the nonuniform state of stress within the central portion of the cross by means of strain gages and applied around the sharp reentrant corners a brittle stress-coat that permitted them to evaluate the biaxial state of stress in the vicinity of the sharp corners. Depending on the shape of the specimens, they carefully reproduced in numerous photographs the various types of fractures and cracks along which these test pieces broke at given, low temperatures, finding tensile cleavage or herring-bone types of fractures.

As to the details, the reader must be referred to the paper itself. They found that the "crack-stoppers" increased the danger of a premature fracture that would start in them in spite of the sharp reentrant corners acting as stress-concentrators and attributed the effect of lowering the fracture load to the presence of the residual stresses due to the reinforcements welded-on. A. Nadai, USA

2534. Jones, M. H., and Brown, W. F., Jr., Creep damage in a CR-MO-V steel as measured by retained stress rupture properties, ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55–A–175, 12 pp. + 19 figs.

It is well known that a material subjected to progressive creep eventually fractures at a time determined by the applied stress and temperature. However, the processes which exhaust the metal ductility in creep are very poorly understood. Until these processes are clearly defined it is not possible to arrive at a satisfactory fracture theory for creep or is it possible to predict intelligently the effects of creep history on the rupture life. The object of the present investigation is to reveal the influence of the following variables on creep damage: (a) Fraction of life exhausted by creep; (b) creep-stress levels resulting in widely different ductilities; (c) combined effects of creep strain and time; and (d) the influence of reheat treatment. In addition, an attempt is made to show the relation between notch sensitivity and creep damage and to discuss a mechanism to explain both these phenomena.

From authors' summary

2535. Emmert, H. D., Investigation of large steam-turbine spindle failure, ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55–A–172, 20 pp.

The low-pressure spindle of a 165,000-kw cross-compound steam turbine burst during a routine overspeed-trip test. An intensive investigation of the design, metallurgy, and manufacture of the spindle and of the operational history of the turbine was completed within four months of the date of the accident.

The nickel-molybdenum-vanadium material currently being specified by the turbine industry for large turbine spindles and generator rotors is known to be susceptible to brittle failure in the presence of notches in heavy sections. It was determined that the initiating cause of the Ridgeland accident was flakes or thermal cracks developed in the shaft during heat treatment. These flaws provided the notches necessary to trigger a catastrophic burst of the shaft.

The incident and subsequent investigation focus attention on the metallurgy, production, and inspection of large turbine-spindle forgings.

From author's summary

2536. Bühler, H., and Schreiber, W., Change of residual stresses in cylindrical metallic bodies due to metal cutting (in German), *Werkstatt u. Betrieb* **88,** 7, 382–388, July 1955.

Starting with equations of Sachs ["Der Nachweis innerer Spannungen in Stangen und Rohaen," *Z. Metallk.* **19,** p. 352, 1927], author derives equations for longitudinal, tangential, and radial stress in a cylinder after any amount of (a) boring of inside diam or (b) turning of outside diam, in terms of the original residual stress pattern. Two examples are presented to illustrate use of derived equations; the first for a hollow cylinder of chrome-nickel steel of 0.27% C, and the second for a solid structural-steel member. In each case changes in residual stress components due to both boring and turning are presented.

M. C. Shaw, USA

2537. Nachtman, E. S., Residual stresses in cold-finished steel bars and their effects on manufactured parts, *Mech. Engng., N.Y.*, pp. 886–889, Oct. 1955.

2538. Frost, N. E., Crack formation and stress concentration effects in direct stress fatigue. Parts I, II, *Engineer, Lond.* **200:** 5201, 464–467, Sept. 30, 1955; 5202, 501–503, Oct. 7, 1955.

2539. Decat, R., How to understand spark erosion, *Amer. Machinist* 100, 9, 113–118, Apr. 1956.

2540. Setterholm, V. C., Heebink, B. G., and Kuenzi, E. W., Durability of low-density sandwich panels of the aircraft type as determined by laboratory tests and exposure to weather, *For. Prod. Lab. Rep., U. S. Dept. Agric.* no. 1573-C, 10 pp. + 6 tables + 4 figs., Oct. 1955.

Three sandwich constructions, consisting of a facing of glass-fabric laminate of 112 fabric, 114 finish (this finish does not impart the best resistance to moisture) on an alkyd-isocyanate foam core, waffle-type glass-fiber core, and a resin-treated paper honeycomb, were tested for durability to high temperature, high humidity, water immersion, and outdoor weathering. From authors' summary

Material Test Techniques

(See Rev. 2775)

Mechanical Properties of Specific Materials

(See Revs. 2441, 2531, 2532, 2534, 2712, 2725)

Mechanics of Forming and Cutting

(See also Revs. 2478, 2536, 2742)

Book—2541. Jeffries, W. R., Tool design, New York, Prentice-Hall, Inc., 1955, v + 217 pp. $6.35.

Book is intended to give students an introduction into the principles of tool design for metal-working machines. It includes a discussion of drill jigs, fixtures for milling, turning, and welding, as well as a detailed treatment of clamping methods. One chapter is devoted to sheet-metal dies, another to a brief description of cutting tools. Although the text is brief, it finds space for advice to the beginner on when to roll up his shirt sleeves. E. G. Loewen, USA

2542. Reicherter, K., Influence of friction and force in extruding of smaller malleable pieces (in German), *Werkstattstech. Maschinenb.* **46,** 2, 89–92, Feb. 1956.

Stress is laid on the role of the resistance of the extrusion stem which, in many cases, can be decreased by a more favorable cross-section length ratio by using higher temperatures and by using graphite or other lubricants. C. Zwikker, Holland

2543. Shchigolev, P. V., and Tomashov, N. D., Investigation of the metal electro-polishing process (in Russian), *Doklady Akad. Nauk SSSR (N.S.)* **100,** 2, 327–330, 1955 (Translated from Russian by M. D. Friedman, 572 California Street, Newtonville, Mass., 6 pp.).

Hydraulics; Cavitation; Transport

(See also Revs. 2460, 2516, 2549, 2652, 2659, 2766, 2782)

Book—2544. Németh, E., Hydrology and hydrometry [Hidrologia és Hidrometria], Budapest, Tankönyvkiadó, 1954, 662 pp. + 32 tables. 96 forints.

Hungary continues her splendid tradition in the field of hydrologic measurements; "Hidrometria" by S. Hajós, published 1906, was the first systematic treatise in Europe. This large volume presents methods of runoff investigations with concise chapters on different parts of hydrology. Contents of the book: Meteorological observations, particularly precipitation; Hydrology: natural circuit, intensity of runoff, infiltration, empirical formulas for average and maximum runoff; River valley, development of river bed; Water-flow fluctuations; Distribution of velocities, formulas for mean velocity; River dynamics: movement of sediments, ice regime; Limnology: lakes, their regime, regulation; Underground water: theories, observations; Seas, tides; Hydrometry: gages, gaging stations, soundings; Velocity measurements: instruments, their rating and use; Graphical determination of river discharge; Volumetric measurement, weirs, flumes; Dilution methods; Water meters, orifices, nozzles, venturi; Traverse method in pipes; Silt measurements; Ice observations; Wave observation; Ground-water measurement; Hydrography: mean and extreme stages, frequency and duration, harmonic analysis; Discharge curve; Storage computation; Unitgraph; Stage forecast and flood-warning service.

32 tables of illustrations and a sample sheet of forecasting service in Hungary are added to this valuable book, which deserves publication in any more easily accessible language than Hungarian. Author showed wide knowledge of subject and good orientation in the international literature. S. Kolupaila, USA

2545. Anonymous, Cavitation at baffle piers, *Wuys. Exp. Sta. tech. misc. Pap.* no. 2–154, 22 pp., Mar. 1956.

Investigation provides information on comparative effects of various shapes of baffle piers on formation and location of cavitation flashes. Tests of 10 different baffle-pier shapes were conducted in variable-pressure, closed-jet water tunnel. Cavitation occurred for all types, although location and intensity were dependent upon pier shape. A chamfer on edges of pier was as effective as a curved surface in lowering point of incipient cavitation.

From summary by J. S. McNown, USA

2546. Anonymous, Investigation of entrance flared in four directions (Entrances to conduits of rectangular cross section, Rep. no. 1), *Wuys. Exp. Sta. tech. Memo.* 2–428, vii + 10 pp. + 21 tables + 21 plates, Mar. 1956. $1.

Paper reports first phase of experimental investigation of the shape of entrances to conduits of rectangular cross section, with useful data for designers, who must keep cross sections as small as possible to avoid cavitation damage. No theoretical solution has yet been provided and probably will not be for a long time. Entrances designed by the procedure of H. A. Thomas and tested by the authors led to unsatisfactory pressure conditions. So, new shapes flared with elliptical curves were investigated in an effort to find the best entrance.

Tests on a model conduit 0.283 ft wide by 0.500 ft high covered conduit normal and at angle with face of dam, and effects of bulkhead guides and of approach channel depth. Test data presented permit determination of expected pressures in critical areas once the set of variables for the case is available. There is, however, an unknown influence, as only one width-depth ratio has been investigated. Some prototype tests have been and are being made to confirm or revise model data. E. O. Macagno, Argentina

2547. Stahl, H. A., and Stepanoff, A. J., Thermodynamic aspects of cavitation in centrifugal pumps, ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55-A-136, 7 pp.

2548. Venkataraman, S., A "null" method of measuring surface tension, with a torsion balance, *Indian J. Phys.* **29,** 11, 522–526, Nov. 1955.

Paper describes a "null" method for the determination of the surface tension of a liquid by the use of a torsion balance. An expression is deduced for the surface tension of a liquid when the pull due to the surface tension acting along the perimeter of a thin glass plate (usually a microscopic cover glass slip) is balanced by the upthrust of the liquid on the partially immersed plate. Results obtained with a few liquids are reported and they agree with the values recorded in the International Critical Tables. This method yields more consistent results than any of the routine methods usually used for the measurement of surface tension. From author's summary

Incompressible Flow: Laminar; Viscous

(See also Revs. 2432, 2438, 2439, 2440, 2442, 2572, 2620, 2632, 2634, 2636, 2652, 2655, 2658, 2660, 2667, 2719, 2720, 2752, 2780, 2781, 2783)

2549. Hughes, R. R., and Oppenheim, A. K., Fluid dynamics, *Indust. Engng. Chem.* **48,** 3 (part 2), 633–654, Mar. 1956.

Fourth annual review of fundamentals of chemical engineering.

2550. Lagerstrom, P. A., and Cole, J. D., Examples illustrating expansion procedures for the Navier-Stokes equations, *J. rational Mech. Analysis* **4,** 6, 817–882, Nov. 1955.

Long expository paper works out Prandtl, Stokes, Oseen, and other expansions for Navier-Stokes equations governing impulsive motion of infinite cylinder which moves axially and expands radially; comparisons with exact solutions for certain cases are given and some useful general conclusions are drawn. C. E. Pearson, USA

2551. Hide, R., The character of the equilibrium of a heavy, viscous, incompressible, rotating fluid of variable density. I. General theory, *Quart. J. Mech. appl. Math.* **9,** 1, 22–34, Mar. 1956.

The combined effects of Coriolis forces and gravitation on the instability of a viscous incompressible fluid are considered. The fluid is assumed to have a variable density in the vertical direction, and to rotate uniformly about an axis that need not be the vertical axis. The problem is solved by the usual method of studying the initial behavior of a small disturbance. The solution is characterized by a variational principle when the system rotates about a vertical axis or when the motion is confined to planes perpendicular to the horizontal component of the angular velocity of rotation.

From author's summary by G. M. Low, USA

2552. Hide, R., The character of the equilibrium of a heavy, viscous, incompressible, rotating fluid of variable density. II. Two special cases, *Quart. J. Mech. appl. Math.* **9,** 1, 35–50, Mar. 1956.

The theory derived in author's previous paper [see preceding review] is applied to two special problems, in each of which the rotation takes place about the vertical axis.

For a continuously stratified fluid of finite depth in which the density increases exponentially, in the vertical direction, the maximum instability depends on the Grashof number and the Taylor number (a measure of the relative dynamical importance of the Coriolis and viscous forces). Instability is shown to be inhibited by the combined influence of viscosity and rotation.

The second case considered is that of two very deep superposed fluids, the upper fluid having a higher density than the lower fluid.

From author's summary by G. M. Low, USA

2553. Einstein, H. A., and Li, H., Steady vortex flow in a real fluid (in French and English), *Houille blanche* **10,** 4, 483–496, Aug.–Sept. 1955.

Viscous theory of a steady drain vortex with a free surface $z = h(r)$ is worked out under assumptions of (a) axisymmetric field about vertical z axis, (b) negligible average z velocity component $\bar{w}$, (c) surface dip negligible with respect to total depth, (d) radial and tangential velocity u and v independent of z, (e) u proportional to radius r, $u = Cr$, above drain opening $r < r_0$. Assumption (e) leads to $w = 2cz$ (which contradicts (b) in $r < r_0$) and to a discontinuous jump of w to zero at $r = r_0$. Authors feel that these discrepancies are negligible, at least near the surface, the experimentally determined shape of which is used as the criterion for validity of the theory.

Under the assumptions, the continuity equation alone determines u in terms of the total volume flux Q_0. The "tangential" momentum equation then reduces to a second-order ordinary differential equation for v in terms of a Reynolds number A (related to flux Q_0) for which solutions in both regions $r \lessgtr r_0$ are easily obtained and "matched" at $r = r_0$. The radial momentum equation is then used to compute surface profiles.

In the experiments, water at measured rate Q_0 was introduced between two glass cylinders rotating at same speeds (from 2 to 80 rpm). It presumably seeped through the lower part of the inner cylinder yielding a known tangential component so that *all* constants in the theory were determined. The photographs of the surface profiles are striking and show the range of parameters tested. The experimental shapes belonged to the theoretical family of shapes but corresponded to values of A "several times smaller" than obtained from measured Q_0 and viscosity ν. Authors believe that this apparent decrease of the effective Reynolds number A_e is due to turbulence and eddy viscosity ϵ, but no values of inferred A_e or ϵ are given.

Some qualitative thoughts on the stability of the drain vortexes and on practical prevention of aspiration of the surface layers (and air) by reduction of A_e are presented.

[See also AMR **6,** Rev. 174. Ed.] M. V. Morkovin, USA

2554. Biesel, F., Remarks on drain vortex phenomena (in French), *Houille blanche* **10,** 4, 497–505, Aug.–Sept. 1955.

In terms of notation of preceding review, present theory consists of solutions of the unsteady "tangential" momentum equation under the assumption of axial symmetry and of radial flows $u = -K/r$, $u = -Cr$, and their combination. Initial non-zero tangential velocity distributions $v(r)$ are seen to grow extremely rapidly as cylindrical slabs of fluid are carried towards the center, in accordance with the principle of conservation of angular momentum. Viscosity effects (away from boundaries) tend merely to "smear" the profiles without changing the basic phenomenon.

Author justifiably feels that these special examples explain the "explosiveness" and "capriciousness" of drain-vortex growth and its "washing away" into the drain. He believes that, for circular basins, the rotation of the earth ω should generally prevail, but recognizes the fact that drain-vortex rotation appears to be statistically independent of ω. He thinks that perfect-fluid reactions of noncircular boundaries maintain a vortex, once generated, even against ω, which may be prevalent away from drain opening. As to its genesis, he looks for explanation to the *low-inertia* viscous layers at the walls propelled by substantially the same forces and pressures as the higher-inertia inner fluid.

Reviewer is skeptical about the last two arguments and would also like to call attention to the fact that disturbed motion in water reservoirs tends to persist for days at magnitudes higher than ω and is, therefore, likely to dominate the "next draining." Thermal convection is also a source of comparable initial disturbances.

M. V. Morkovin, USA

2555. Schiebeler, W., Rotational air flow in a circular tube behind radial guide vanes (in German), *Mitt. Max-Planck-Inst. Strömungsforschung* no. 12, 101 pp., 1955.

Results of detailed experiments are given for incompressible flow and compared with theoretical methods of calculation. Rotational flow produced by twisted vanes was unstable and similar to that produced by untwisted vanes. Velocity distributions were determined by measurements of pressure, angle, and temperature of flow. A kernel of this flow always exists near the axis of the tube. Diameter of this kernel depends on flow direction at the wall of tube, while decreasing temperature at the axis is closely associated with the rotational energy per unit time.

Two different coaxial rotational flows show that an initially existing difference vanishes in a distance twice the tube diameter. The order of magnitude of the process which produces a kinetic energy transport in axial direction is discussed by author. F. Keune, Germany

2556. Rott, N., Unsteady viscous flow in the vicinity of a stagnation point, *Quart. appl. Math.* **13,** 4, 444–451, Jan. 1956.

The flow field near a stagnation point of an incompressible fluid when the plane performs several types of motions in its own plane is investigated. Exact solutions of the Navier-Stokes equations are obtained for the steady motion and the exponentially accelerating motion of the plate in its own plane and in the plane of the two-dimensional stagnation flow. Approximate solutions for an oscillating plate are obtained for the limiting cases of low and high frequencies, and discussed. It is shown that the high-frequency solution is fairly well approximated by the Stokes's solution. In both cases, the plate oscillation leads to both in-phase and out-phase shearing stresses. It is further noted that, if the plate temperature is constant as well as the stream temperature, the heat-transfer rate will not be affected by the motion of the plate in its own plane. Similar problems in the case of three-dimensional stagnation-point flow are also noted and several approximate results are obtained. S.-I. Cheng, USA

2557. Binnie, A. M., The effect of viscosity upon the critical flow of a liquid through a constriction, *Quart. J. Mech. appl. Math.* **8,** 4, 394–414, Dec. 1955.

Paper considers two problems on critical flow of liquids: flow over a broad-crested weir, and swirling flow through a converging-diverging nozzle. The first serves as a relatively simple introduction to the method, which follows the Pohlhausen-von Karman treatment of boundary layers. The second is of greater significance, since it approximates flow in the widely used swirl-atomizers. Following earlier work by G. I. Taylor [AMR **4,** Rev. 1234] and the author[AMR **4,** Rev. 1233], present paper shows, by mathematical analysis and numerical examples, the significant changes in calculated velocity and surface profiles arising from allowance for viscosity. Detailed development includes both inviscid and viscous flow, and shows the effect of standing waves.

Reviewer feels paper is a valuable contribution toward a quantitative theory of these swirling flows. Further study of numerical examples would aid in treatment of the engineering problem.

R. R. Hughes, USA

2558. Kiselev, A. A., Solution of the linearized equations of non-steady viscous incompressible fluid flow in a bounded region (in Russian), *Dokladi Akad. Nauk SSSR (N.S.)* **101,** 1, 43–46, 1955 (translated from Russian by M. D. Friedman, 572 California St., Newtonville, Mass., 7 pp.)

Existence and uniqueness theorems are presented for the boundary problem for three space variables. Specific types of functions are considered. Certain results obtained for the steady-flow problem are used.

R. C. Binder, USA

2559. Anzelius, A., Two flow problems in a viscous fluid, *Ark. Fysik* **9,** 5, 391–398, 1955.

An analytical study is presented of two-dimensional viscous flow in a channel formed by a sector and in a strip (channel formed by parallel walls). Starting with the Navier-Stokes equations, an approximate solution for the stream function is obtained by expanding in powers of the reciprocal of kinematic viscosity. Streamlines are given for the sector and the strip. R. C. Binder, USA

2560. Nickel, K., On special systems of cascades of lifting surfaces. II, Theory of thin profiles (in German), *Ing.-Arch.* **23,** 2, 102–118, 1955.

Plane, inviscid, incompressible flow is assumed. Cascade airfoils are represented by vortex and source distributions on infinite equally spaced parallel chords; zero stagger or 90° stagger (in-line airfoils) is considered. The case of a lattice of several parallel cascades is considered under the assumption that all pitches are equal and that the airfoils of adjacent cascades are coplanar or displaced by half a pitch. Several examples are worked out. P. Cicala, Italy

2561. Fritzsche, A., The mechanism of flow in cascades, *Sulzer Tech. Rev.* **37,** 3, 53–65, 1955.

With the objective of perfecting the blading of their axial compressors and turbines, Sulzer Brothers have long made a study of general problems of flow in cascades. Author discusses a few of the results obtained.

A vortex model suggested by Traupel for the representation of flow in cascades is first described. A description is then given of the flow.

A vortex model suggested by Traupel for the representation of flow in cascades is first described. A description is then given of the flow patterns produced in a wind tunnel by the lamp-black coating method, which enables the effects of these vortex systems to be clearly observed. The analyses of further flow patterns underline the importance of this method of investigation for the study of flow phenomena.

From author's summary

2562. Kearton, W. J., The flow of air through radial labyrinth glands, *Proc. Instn. mech. Engrs.* **169,** 30, 539–552, 1955.

Flow through radial glands is treated by an extension of the theory of axial labyrinth glands. Dependence of leakage on pressure ratio is expressed by means of a discharge coefficient C. Experiments are described, yielding fairly large variations of C with pressure ratio. Pressure distribution over the rings is found to agree very well with theory. L. J. F. Broer, Holland

2563. Grootenhuis, P., A correlation of the resistance to air flow of wire gauzes, *Proc. Instn. Mech. Engrs.* **168,** 34, 837–846, 1954.

The resistance to the flow of air through different assemblies of wire gauzes has been correlated to a common basis. Single gauzes, closely-packed assemblies, sintered packs, and assemblies of spaced gauzes have been considered, although the actual correlations have been restricted to square-mesh gauzes with a single-wire diameter, as these are used most in practice. Experimental data for the sintered packs are presented and compared with the published data for the other types of assembly.

The flow of air through a gauze is considered as analogous to flow through passages or pipes, and the resistance as being due mainly to the friction between the flow and the surfaces of the voids in the gauze, in contrast to the previous approaches of treating the resistance of a gauze as being due to a combined drag of the wire cylinders. The range of Reynolds number (based on hydraulic mean diameter) covered by the correlation is from 0.1 to 5000. From author's summary

2564. Yuan, S. W., Further investigation of laminar flow in channels with porous walls, *J. appl. Phys.* **27,** 3, 267–269, Mar. 1956.

Author solves what is, in effect, the differential equation of two-dimensional stagnation flow in a viscous fluid, for boundary conditions appropriate to the problem of the title when the velocity of flow through the walls is independent of position. The Reynolds number R, based on the half-width of the channel and the velocity of flow through the walls, is assumed to be large, and the solution is assumed to possess an expansion in negative powers of R. The terms in R_0 and R^{-1} are obtained explicitly, together with the corresponding results for the pressure gradient and drag coefficient.

While the author's solution is probably satisfactory as a numerical approximation when $R > 10$, reviewer thinks it rather unlikely that the solution possesses an expansion of the assumed form. Support for this criticism is provided by the logarithmic singularity at the center of the channel which appears in the term in R^{-1}.

I. Proudman, England

2565. Yates, E. C., Jr., On the permeability of porous materials, *NACA TN* 3596, 31 pp., Jan. 1956.

The permeability characteristics of a metal wire cloth and two sintered bronze samples were studied as a function of Mach modulus, Reynolds modulus, and the mechanical treatment of the sample.

Methods of calibrating porous materials and of extrapolating and of interpolating calibration data are recommended for use in the design of area suction installations. W. L. Sibbitt, USA

2566. Anton, L., Formation of a vortex at the edge of a plate, *NACA TM* 1398, 36 pp., Mar. 1956.

The flow about the plate of infinite width may be represented as a potential flow with discontinuity surfaces which extend from the plate edges. For prescribed form and vortex distribution of the discontinuity surfaces, the velocity field may be calculated by means of a conformal representation. One condition is that the velocity at the plate edges must be finite; but this is not sufficient for determination of the form and vortex distribution of the surface. However, on the basis of a

similitude requirement one succeeds in finding a solution of this problem for the plate of infinite width which is correct for the very beginning of the motion of the fluid. Starting from this solution, the further development of the vortex distribution and shape of the surface are observed in the case of a plate of finite width.

From author's summary

2567. Horlock, J. H., Some experiments on the secondary flow in pipe bends, *Proc. roy. Soc. Lond. (A)* **234,** 1198, 335–346, Feb. 1956.

Author investigates analytically the behavior of the secondary flow in a bend in which the radius of curvature is repeatedly reversed. He uses for analysis a bend whose center line is in the form of a sine curve. The differential equation derived is nonlinear, and he presents his solutions to the equation for different entrance conditions.

An experimental system was set up to approximate a sinusoidal pipe and was tested, using air as fluid, and relatively close agreement was apparently obtained between analytical and empirical results.

Author concludes that large secondary velocities, associated with large pressure losses in pipes and scouring of river beds, may be produced in pipe bends in which radius of curvature is repeatedly reversed.

J. S. Marcus, USA

2568. Starkey, T. V., The laminar flow of streams of suspended particles, *Brit. J. appl. Phys.* **7,** 2, 52–55, Feb. 1956.

It is shown by experiment as well as by theory that suspended particles in a laminar flow follow a path which deviates from the streamlines as soon as the fluid is under shear. The lateral force which acts on the suspended particle increases with the particle size, the mean rate of shear in the suspension, and with the distance from the tube axis, and is directed towards this axis. The explanation of this phenomenon can be found when the velocity and the rotation of the particle is considered in comparison to the continuous phase. Reference is made to the principle of least action to the motion of a particle through a viscous fluid under shear [AMR **8,** Rev. 3443].

J. A. Businger, Holland

2569. Srinivas, V., Rao, V. S., and Rao, M. N., Disk atomization, *J. sci. indust. Res., India* **15A,** 1, 29–33, Jan. 1956.

In the spinning disk atomizer, the liquid is fed at the center of a rotating disk which accelerates the liquid centrifugally to high velocity and discharges it at the periphery of the disk in the form of spray. Numerous patterns of the disks, each giving a different performance, have been evolved. Performance characteristics are weight distribution, drop-size distribution (compact and dense, or widespread spray) and power requirements. The power input is mostly used up by the drive of the disk, and, to a less extent, to overcome the friction of flow across the disk and the kinetic energy imparted to the drops; the power spent in creating the extra surface is only a very small portion of the energy. Marshall and Seltzer's equations for the viscous flow across the revolving disk is explained.

An attempt is made to determine experimentally the actual velocity of the drops leaving the disk. Brass disks, about 2-in. diam, were driven at speeds from 1000 to 10,000 rpm with the disk mounted vertically on a horizontal spindle, photographs were taken of drops traveling vertically upwards, at the upper region of their trajectory where their velocity was already reduced by gravitational force and by air resistance; the streak width of the drop image was measured with a traveling microscope. Results are given in a sample calculation and in tabulated representation.

Developing a realistic theory is complicated by the air-aspiring action of the disk, frictional drag between the disk surface and the air, and transfer of momentum to the air from the spray. Work is in progress on effect of feed rate, disk design, and velocity on the size of the drops and their leaving velocity.

K. J. De Juhasz, Germany

2570. Lehnert, B., An instability of laminar flow of mercury caused by an external magnetic field. (A discussion on magneto-hydrodynamics), *Proc. roy. Soc. Lond. (A)* **233, 1194, 299–302, Dec. 1955.**

Author describes elegant experiments in which mercury in a shallow tray under a vertical magnetic field is stirred slowly by means of a rotating annular section of the copper base of the tray. As field intensity is increased from 0 to 8000 gauss, only the mercury directly above the rotating annulus rotates, and two vortex rows appear in the regions of high velocity gradient at the edges of the rotating mercury. The phenomenon appears to be the usual instability of vortex sheets, here generated by magneto-hydrodynamic effects.

J. A. Shercliff, England

2571. Drescher, H., Measurement of time variable pressures exerted on a cylinder with cross flow (in German), *Z. Flugwiss.* **4,** 1/2, 17–21, Jan./Feb. 1956.

The change of pressure with time at 11 stations on the surface of a circular cylinder was measured in water. The vortexes in the wake were photographed by a synchronized camera. The effect of drag as a result of the periodic change in the forces perpendicular to the flow direction and the vortex frequency were determined. Though considerable variations in the amplitude of the pressure fluctuations were observed, good agreement of the dimensionless frequency with results obtained elsewhere in air and water was obtained.

At a Reynolds number of about 2×10^5, critical flow was reached and the vortexes followed a different law, which resulted in a sudden marked increase in the dimensionless vortex frequency. At even high Reynolds numbers, the pressure fluctuations became too small to allow a determination of the vortex frequency with this method.

H. J. Ramm, USA

Compressible Flow, Gas Dynamics

(See also Revs. 2432, 2549, 2550, 2625, 2635, 2639, 2641, 2643, 2644, 2648, 2676, 2679, 2683)

2572. Baños, A., Jr., Magneto-hydrodynamic waves in incompressible fluids. (A discussion on magneto-hydrodynamics), *Proc. roy. Soc. Lond. (A)* **233,** 1194, 350–366, Dec. 1955.

General linearized theory of plane and cylindrical waves in inviscid conducting fluids under a uniform imposed magnetic field, studied previously by author [*Phys. Rev.* **97,** 1435–1443, 1955], is now employed to deduce propagation characteristics in the three cases: infinite conductivity, slight ohmic damping, and slight magneto-hydrodynamic coupling. Displacement current is not neglected. Separate modes are discerned, some devoid of pressure fluctuations. Author studies the interplay of magneto-hydrodynamic effects with ordinary electromagnetic waves and acoustic waves (in the compressible case).

Reviewer considers that author has done a useful service in bringing together many known results and some fresh ones in a systematic manner.

J. A. Shercliff, England

2573. Marshall, W., The structure of magneto-hydrodynamic shock waves. (A discussion on magneto-hydrodynamics), *Proc. roy. Soc. Lond. (A)* **233,** 1194, 367–376, Dec. 1955.

Author derives the momentum, energy, and electric field equations governing conditions within a plane shock wave in an ionized gas, when varying magnetic fields perpendicular to the motion occur. Charge convection and the Hall effect are shown to be of minor importance. Two characteristic lengths αl and βl emerge, where, for the undisturbed gas, l is roughly the mean free path, α is a reciprocal Prandtl number, and β is another dimensionless fluid property proportional to the magnetic/momentum diffusivity ratio. α is somewhat larger than unity because, in the main, ions transfer momentum, while electrons transfer heat. β may be very large or very small, and typical solutions are found in each case. When β is small (high conductivity), the shock thickness is of order αl. When β is large, the thickness is of order βl, and when the initial field is strong enough, the variables never change abruptly within the so-called shock.

Viscosity, thermal and electrical conductivities are taken as varying as powers of absolute temperature. Relaxation phenomena are not considered.

Reviewer feels results could be more fully explained in terms of the diffusivities of momentum, magnetic field, and heat. The physical possibility of occurrence of such shocks, which contain a current sheet, is not discussed. The work is, however, one of the few solutions of the full, nonlinear, compressible, magneto-hydrodynamic equations so far produced, although variation is permitted in one dimension only.

J. A. Shercliff, England

2574. Hide, R., Waves in a heavy, viscous, incompressible, electrically conducting fluid of variable density, in the presence of a magnetic field. (A discussion on magneto-hydrodynamics), *Proc. roy. Soc. Lond. (A)* **233,** 1194, 376–396, Dec. 1955.

Author develops small perturbation theory for waves under vertical gravity and magnetic fields where fluid density varies with height. The fluid is incompressible and of uniform conductivity. Following Rayleigh, author shows that growth rates evaluated from assumed vertical variations of the perturbations will not be seriously in error. Growth rates are found in the two cases: uniform fluid properties (ordinary magneto-hydrodynamic waves), and infinite conductivity with a small exponential variation of density and viscosity. The upper and lower fluid boundaries are, paradoxically, both free surfaces at which, however, no vertical motion occurs. When the density decreases as height increases, the decay of perturbations may or may not be oscillatory, with waves occurring, depending on wave number. Less restrictive conditions are to be considered in a later paper.

J. A. Shercliff, England

2575. Shapiro, A. H., Wadleigh, K. R., Gavril, B. D., and Fowle, A. A., The aerothermopressor—a device for improving the performance of a gas-turbine power plant, *Trans. ASME* **78,** 3, 617–653, Apr. 1956.

Theoretical and experimental investigations of a novel gas-dynamics device, having no moving parts yet performing the function of a compressor, are described. This device, called the "aerothermopressor", exploits the possibility of raising the total pressure of a high-speed gas stream through cooling of the gas. When placed at the exhaust of a gas turbine, the aerothermopressor will reduce the exhaust pressure, thereby improving both fuel economy and power capacity per unit of air flow. Basic elements of the apparatus comprise a nozzle which accelerates hot gas into an evaporation section; a water-injection system which delivers finely atomized water into the high-speed stream; an evaporation section in which the gas is cooled and most of the water evaporated; and, finally, a diffuser in which the gas stream is decelerated and the static pressure increased.

From authors' summary by A. K. Oppenheim, USA

2576. Weinig, F. S., Subsonic influence of compressibility on the pressure distribution of a profile, *J. aero. Sci.* **23,** 3, 279–281 (Readers' Forum), Mar. 1956.

For subsonic compressible flow about a profile, the differential equations for ϕ and ψ in hodograph plane deviate from Laplace's equation only by a first-order derivative term which contains a coefficient depending on the magnitude of velocity vector. By actually computing this function, author was able to show that, for moderate values of local Mach number M, this term can usually be neglected. Thus it was contended that to justify the use of Laplace equation for ϕ and ψ in hodograph plane, Karman-Tsien's linearized $p - 1/\rho$ relationship (i.e., imposing $\kappa = -1$) is not expedient.

Author next carried out a detailed analysis of gas dynamic relationship and, by restricting to flow regions away from stagnation point, arrived at the following improved form of pressure coefficient formula:

$$C_p = \frac{C_{pi}}{\sqrt{1 - M_\infty^2} + \frac{C_{pi}}{2} M_\infty^2 \frac{1}{1 + \sqrt{1 - M_\infty^2}} + \frac{\kappa + 1}{4} \frac{M_\infty^2}{1 - M_\infty^2}}$$

which for $c_{pi} \to 0$ goes over into Prandtl-Glauert formula; and for $\kappa = -1$, to Karman-Tsien formula. It was pointed out that the term containing $(\kappa + 1)$ also appeared in Kaplan's second-order result for compressible flow about an elliptic cylinder.

Several misprints are noted; in particular, there is a typographical error in the sign in Eq. (15) of original paper.

H. S. Tan, USA

2577. Bergman, S., On representation of stream functions of subsonic and supersonic flows of compressible fluids, *J. rational Mech. Analysis* 4, 6, 883–905, Nov. 1955.

Paper investigates potential adiabatic compressible flows by means of a modified hodograph technique in which the flow is examined in a "pseudo-logarithmic" plane whose Cartesian coordinates are θ, the angle which the velocity vector forms with the positive direction of the x-axis, and λ, which is a logarithmic function of the local Mach number. The differential equations of motion, with the stream and potential functions as independent variables, are then shown to assume a relatively simple form in the case of subsonic flows. It is next shown that a flow which in the physical plane is bounded by segments of straight lines and segments of free boundaries corresponds in the pseudo-logarithmic plane to a flow bounded by segments of lines which are parallel to the axes λ and θ. Examples of flow patterns of this type are given.

Finally, flows of a mixed type are investigated where θ and a function of λ, (H), are the independent variables, with the stream function ψ as dependent variable. Assuming ψ to be an analytic function of H and θ, bounds for ψ are derived. R. F. Probstein, USA

2578. Manwell, A. R., A family of plane compressible flows past a certain semi-infinite body, *J. Math. Phys.* **34,** 2, 113–118, July 1955.

2579. Dombrovskiĭ, G. A., Integration of equations related to the plane-parallel steady potential motion of compressible fluids (in Russian), *Doklady Akad. Nauk SSSR (N. S.)* **103,** 1, 31–34, 1955.

The velocity potential ϕ and stream function ψ satisfy

$$\partial\phi/\partial\theta = (\pm K)^{1/2}\partial\psi/\partial s, \quad \partial\phi/\partial s = \mp(\pm K)^{1/2}\partial\psi/\partial\theta \qquad [1]$$

where

$$-(\pm K)^{1/2}\, dv^{-1}/ds = 1/\rho v, \quad d(\rho v)^{-1}/ds = \mp(\pm K)^{1/2}/v \qquad [2]$$

Here $ve^{i\theta}$ is the velocity, K is a known function of v, ρ and v are defined as functions of s by [2], upper signs refer to subsonic, lower signs to supersonic flow.

Author proposes to approximate K by $[n \tanh m(s - s_0)]^4$ in subsonic flow, and $-K$ by $[n \tan ms]^4$ in supersonic flow, where n, m, s_0 are constants. Then [2] can be integrated explicitly, and the general solution of [1] for these choices of K can be found in terms of several arbitrary functions. The various constants involved can be chosen to yield a third-order approximation to the usual adiabat $p = p(\rho)$ at a value of ρ corresponding to a given v. The arbitrary functions can be used to satisfy boundary conditions. J. H. Giese, USA

Book—2580. Keune, F., Report on the theory of flow around bodies of revolution with 0 angle of attack at M = 1 [Bericht über eine Theorie der Strömung um Rotationskörper ohne Anstellung bei Machzahl Eins], (Forschungsberichte des Wirtschafts- und Verkehrsministeriums Nordrhein-Westfalen no. 218), Koln und Opladen, Westdeutscher Verlag, 1955, 25 pp.

In this summarizing report, the linear theory applicable to sub- and supersonic flow speeds is first reviewed briefly. For transonic speeds it is proposed to adopt the familiar nonlinear differential equation of von Karman, but to replace the factor $\partial u/\partial x$ by a constant, $1/a^2$, thus linearizing the equation and rendering it parabolic. This approximation is suggested only for half-bodies or the front parts of fusiform bodies. When a sonic line is encountered, the flow farther aft may be determined by a characteristics method in place of the parabolic approximation. For bodies on which a region of decreasing velocities occurs, a characteristics procedure is required near and behind the maximum-speed point. Results of this theory are collected. Some results that suggest reasonable values of the constant a^2 are presented. Comparison of computed and measured pressure coefficients on half-bodies (ogives) is made, and the agreement is found to be very good.

This theory, which was suggested by K. Oswatitsch, was also reported on in a paper by Oswatitsch and Keune [Proc. Conference on high-speed aeronautics, Polytech. Inst. Brooklyn, January 20–22, 1955, pp. 113–131]. W. R. Sears, USA

2581. Miles, J. W., On the sonic drag of a slender body, *J. aero. Sci.* **23,** 2, 146–154, Feb. 1956.

Problem for an axial symmetric body at transonic speeds is a nonlinear one even with small perturbation approximations. However, near the body the linearized slender-body approximation may be applicable for sufficiently slender bodies. At a far distance from the body, the nonlinear behavior of the flow for Mach number one was found by Guderley and the reviewer. This solution corresponds to the doublet singularity in incompressible flow, but, unlike the latter, there is no connection in the asymptotic solution with a body parameter such as the slenderness ratio, nor with the origin of the axial coordinate relative to the body.

The present paper attempts to find the flow over a body using the

linearized theory near the body and the asymptotic solution away from the body and matching the two at a point along the sonic line where the two solutions might be valid. Only an approximate solution can be obtained in this way since the two solutions do not have a common domain of validity; moreover, the match at a point on the sonic line between the two solutions does not guarantee a match between them at any other point.

The fore drag of a cone-cylinder body at Mach number one is computed in this way, and the results obtained compare with those by the reviewer with a numerical method on the nonlinear equations. (It should be pointed out that in the reviewer's paper, in the conversion of the computed velocity distribution to the pressure distribution over the conical nose with the simplified Bernoulli equation, the sign of the usual second-order term, the flow inclination squared, is in error so that the pressure coefficients along the cone must be decreased by half the square of the nose angle of the cone. With this correction, excellent agreement with experiment results.)

H. Yoshihara, USA

2582. Cole, J. D., and Messiter, A. F., Expansion procedures and similarity laws for transonic flow, Part I. Slender bodies at zero incidence, *Calif. Inst. Tech. Guggenheim Aero. Lab., OSR Tech. Note* 56-1, 39 pp., Jan. 1956.

This report provides a detailed and comprehensive account of a transonic approximation as applied to flows past wings and bodies. It is mainly concerned with the derivation of approximate equations, boundary conditions, etc., rather than with the more difficult problem of the solution of transonic flow problems. Thus the report contains, for the most part, a re-examination of the basic ideas. The essential new point of view introduced here is to regard the approximate transonic equations as part of a systematic expansion procedure. Thus it becomes possible, in principle, to compute the higher terms of this approximation or at least to estimate errors. The expansion is carried out in terms of a decreasing sequence of functions of the thickness ratio, and a similarity parameter relating the Mach number and thickness ratio is introduced. The first few terms of the expansions of the velocities near the axis are obtained, and similarity laws are derived for the pressure coefficient and drag coefficient of a body at zero incidence. By means of another expansion, an approximate "area rule" is obtained for a body of noncircular cross section.

From authors' summary M. H. Bertram, USA

2583. Wu, T. Y.-T., Two-dimensional sink flow of a viscous, heat-conducting, compressible fluid; cylindrical shock waves, *Quart. appl. Math.* **13,** 4, 393-418, Jan. 1956.

The problem of the steady cylindrical source-type or sink-type flow has been of interest to fluid-dynamicists for several reasons. First, it is known that the corresponding problem of an inviscid compressible fluid has an exact solution containing a limit line of rather special type, namely, the sonic circle. To the exterior of this circle the solution has two branches of values, one has its stagnation point at infinity (subsonic branch) and the other starts with maximum velocity at infinity (supersonic branch). Both of these two branches terminate at the limit line with infinite velocity gradient. Therefore the viscous and heat-conductive effects are expected to play an important role in continuing the solution further inward. Second, because of its cylindrical symmetry, this problem is one of the few nonlinear flows in more than one dimension for which there is only one independent variable, the radial distance. Consequently, the equations are simple enough to allow a unified discussion of the various effects.

In the first part of this investigation, the Navier-Stokes equations are given for the cylindrical sink flow of a viscous, heat-conducting, perfect gas. Then, with some simplifying assumptions, the qualitative properties of the solutions are discussed in detail for the case of large Reynolds number Re, based on the radius of the sonic circle and on the speed of sound.

In the second part of this paper, the detailed calculation of the solution is carried out for the case of large Re. It is found that there is no single expression available for the solution uniformly valid in the entire flow region. The calculation is then performed in three different regions characterized by the length r_1 and the parameter Re. In the transonic region, the solutions belonging to the supersonic branch contain cylindrical, shock-type flow. The shock strength is of $O(Re^{-1/3})$ while the shock thickness is of $O(Re^{-2/3})$; these results are quite different from those for plane normal shock.

From author's summary by J. Kestin, USA

2584. Michel, R., and Sirieix, M., Experimental study of a lifting surface in transonic flow (in French), *ONERA NT* 26, 22pp., 1955.

The determination of pressure distributions on an NACA 64-A-010 profile, at moderate incidence and for a range of Mach numbers between 0.6 and 1, has permitted the analysis of the influence of the unsymmetric development of shock waves from the upper and lower faces, upon the lift and moment coefficients.

This exploration of the transonic region was completed with a study at a free-stream Mach number of one for an incidence range to six degrees.

At this Mach number the measured pressure distributions for profiles 64-A-006 and 64-A-010 confirmed von Karman's rules for similitude in transonic flow.

From authors' summary by M. J. Goglia, USA

2585. Kryuchin, A. F., Problem for a transonic flow around an airfoil (in Russian), *Prikl. Mat. Mekh.* **18,** 5, 547-560, Sept.-Oct. 1954.

Tricomi's equation expressing von Karman's first approximation to plane transonic flow past an airfoil is deduced, and method of solution is given in detail for the problem of a diamond symmetric airfoil without incidence, $M_\infty > 1$ and a curved detached schock wave ahead of the airfoil.

G. Moretti, Argentina

2586. Samoilovich, G. S., Investigation of aerodynamic gratings at high, near-sonic, and supersonic velocities (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 9, 80-84, Sept. 1954.

Several static and pitot tubes, and yawmeters in use in Moscow Energy Institute, are briefly described, with a schematic diagram of an electronic ancillary equipment. Instruments are claimed of very high efficiency in transonic and supersonic flow.

G. Moretti, Argentina

2587. Keune, F., and Oswatitsch, K., An integral equation theory for the transonic flow around slender bodies of revolution at zero incidence, *Roy. Inst. Technol. Div. Aero., Stockholm, KTH-Aero TN* 37, 78 pp. + 20 figs. + 24 tables, Aug. 1954.

The integral equation for calculating the flow over slender bodies of revolution which are pointed at the front and rear is derived by the method of K. Oswatitsch using the gas dynamic equation for axisymmetric transonic flow. A certain function is assumed for the variation in velocity at radial distances from the body. The integral equation can thus be reduced to line integrals for calculating the velocity on the axis of the body. The integrals are analyzed into finite sums of strips of equal width. The coefficients of this numerical integration are calculated separately as matrixes.

This theory is presented here without calculations of examples in the transonic range because the time was not available to overcome some difficulties in numerical calculations for supercritical Mach numbers in the subsonic flow. The comparison of the linear and nonlinear subcritical flow shows a sufficient agreement up to high subsonic Mach numbers.

From authors' summary by E. V. Laitone, USA

2588. Landahl, M., The flow around oscillating low aspect ratio wings at transonic speeds, *Roy. Inst. Technol. Div. Aero., Stockholm, KTH-Aero TN* 40, 24 pp. + 7 figs., 1954.

Work starts with three-dimensional unsteady velocity equation limited to second-order terms. It sketches size-order analysis following Lin, Reissner, Tsien [AMR **3,** Rev. 120], resulting in four linear and two nonlinear equations for unsteady perturbation potential under several explicitly established order conditions.

Author begins solution with customary linearized equation for sub- and supersonic cases in moving coordinates. He gives solutions for these cases as integrals over "retarded" dipole distributions. Problem is transformed into Fourier space for stream direction. Both solutions are shown to have same spectral density: an integral representation over a first-order Hankel function of second kind. Author specializes problem maintaining transonic linearization conditions imposed by setting $M = 1$ in common Fourier distribution.

Treatment expands representation close to body with boundary condi-

tion on derivative normal to loaded plane. Expansion is inverted into physical plane and solved by iteration procedure described by Sears and Adams [AMR **6**, Rev. 3136], based on recognition that first iteration consists of inversion formula for a familiar integral equation treated by Schröder, Söhngen, and others.

Solutions are given for rigidly oscillating delta in heave and roll to the third, and pitch to the second, order. Expressions are given for complex amplitudes of force coefficients. Solutions for symmetric bending and antisymmetric torsion to second order with complex force coefficients are presented.

Solutions are applied to dynamic stability coefficients. It appears that only acceleration derivatives realize unsteady flow effects to first order in frequency and show characteristic transonic logarithmic dependence on frequency. This dependence is claimed not valid as zero frequency is approached, as it is incompatible with conditions for transonic linearization. Other stability derivatives are established by slender-body theory. At $M = 1$, damping becomes negative for too high aspect ratio: stability deteriorates for low aspect ratio and M about 1.0 at lower reduced frequencies. Results on damping compare well with Watkins [AMR **7**, Rev. 2247; AMR **5**, Rev. 481] for not too low frequencies. Third-order results for complex force coefficients in heave compare well with Watkins [loc. cit.] for delta of aspect ratio 1.5 at M of 1.10 and 1.22. Results agree with a so-called "high-frequency" solution [AMR **6**, Rev. 3175] only at very low aspect ratios and reduced frequencies.

Three orders of solutions are compared for complex coefficients in heave and roll at $M = 1.0$. Slender-body solutions are acceptable only at very small aspect ratios and reduced frequencies.

P. R. Hardesty, USA

2589. Weil, J., Campbell, G. S., and Diederich, M. S., An analysis of estimated and experimental transonic downwash characteristics as affected by plan form and thickness for wing and wing-fuselage configurations, *NACA TN* 3628, 92 pp., Apr. 1956.

Paper presents a summary of the effects of changes in wing planform and thickness ratio on the downwash characteristics of wing and wing-fuselage configurations in the Mach number range between 0.6 and 1.1. Data obtained by the transonic-bump technique at two tail heights have been compared with theoretical estimations made in the subsonic and supersonic Mach number range. From authors' summary

2590. Phillips, W. H., and Thompson, R. F., Investigation by the transonic-bump method of a 35° sweptback semispan model equipped with a flap operated by a series of servovanes located ahead of and geared to the flap, *NACA TN* 3689, 39 pp., Apr. 1956.

Lift, drag, pitching-moment, rolling-moment, and yawing-moment data in the Mach number range from 0.6 to 1.0 obtained from wind-tunnel tests of a low-aspect-ratio sweptback airfoil model with a servovane control are presented. The control utilizes the drag force and spoiler action of a set of vanes to deflect a flap-type control. Comparison of lift increment and center-of-pressure location is made with previously published data from tests of a conventional flap-type control.

From authors' summary

2591. Kuo, Y. H., Viscous flow along a flat plate moving at high supersonic speeds, *J. aero. Sci.* **23**, 2, 125–136, Feb. 1956.

The hypersonic boundary-layer interaction problem is treated by Lighthill's coordinate stretching method [AMR **3**, Rev. 1829] rather than by Lee's method [AMR **6**, Rev. 3146] of similar solutions. Results are similar except near the leading edge, where there is a reduction in skin friction. It is also predicted that the shock is attached with a definite finite slope and that the initial boundary-layer growth is like $x^{3/2}$.

S. A. Schaaf, USA

2592. El Badrawy, R. M., Flat plate cascades at supersonic speed, *NACA TM* 1369, 130 pp., May 1956.

See AMR **6**, Rev. 3840.

2593. Goodman, T. R., Dynamic derivatives in yaw and sideslip of thin wings at supersonic speeds, *J. aero. Sci.* **23**, 4, 357–367, Apr. 1956.

Author develops linearized theory for two wing motions that present special difficulties: (a) constant angular velocity of yaw r; (b) same, plus rate of sideslip $\dot{\beta} = r$. To fit case (a), governing equations are derived for a circular flight path. Expansion of potential to $O(r)$ leads to a zero-order problem governed by Prandtl-Glauert equation plus a first-order problem dependent on inhomogeneous (curvature) term. A solution is obtained for "infinite" sweptback wing, leading to pressure distribution and derivative C_{l_r}; a development for slender wings is also given. (Reviewer notes that author's adjectives "infinite" and (later) "two- dimensional" are improper: the linearization in r requires wing span $\ll$ turn radius; there is, however, no upper limit on AR.)

Case (b) implies rectilinear motion of wing reference point plus yawing about this point. Gardner method for nonsteady motion [AMR **4**, Rev. 2124] is applied, leading to two equivalent steady-motion problems which are solved by integration of sources. Integration is carried out for infinite sweptback, wide delta, and rectangular wings, and values of $C_{l_r} + C_{l_{\dot{\beta}}}$ are obtained for latter two.

Procedures and many of the results appear to be new. Analysis of case (a) for slender delta and for unswept two-dimensional wing (included above as special cases) originated with reviewer some eight years ago [AMR **1**, Rev. 695; **3**, Rev. 2450; cf. also AMR **2**, Rev. 96].

H. S. Ribner, Canada

2594. Eggers, A. J., Jr., Resnikoff, M. M., and Dennis, D. H., Bodies of revolution having minimum drag at high supersonic airspeeds, *NACA TN* 3666, 38 pp., Feb. 1956.

Paper presents (1) a simple analytical method for estimating the shape of axisymmetric bodies having minimum pressure foredrag at supersonic Mach numbers, in excess of say 2.5, and (2) supersonic tunnel measurements on several bodies of fineness ratios 3 and 5 tested at Mach numbers from 2.73 to 6.28. The analysis, based simply upon Newton's law of resistance and the calculus of variations, was carried out for various combinations of body length, base diameter, surface area, and volume.

Results indicate that for fixed length, the minimum-drag body has a blunt nose; otherwise a sharp nose results. Tests indicate that the theoretical minimum-drag bodies were reasonable approximations to the correct shape, that the centrifugal forces in the flow about bodies curved in the stream direction may influence their drag, and that this influence was predictable by a simple modification to the theory.

Reviewer believes simplicity and apparent reliability of the method makes it a useful tool for missile designers.

R. E. Bolz, USA

2595. Vandrey, J. F., Interference between a straight wing and a fuselage at zero lift in supersonic flow (in German), *Z. Flugwiss.* **4**, 1/2, 44–46, Jan./ Feb. 1956.

Supersonic wing-body-interference drag problem is investigated in the frame of linear theory. Integral formulas are given for the disturbance produced by the wing on the fuselage and vice versa, where reversal flow rule is used. In the special case of the infinite straight wing, a very simple formula results, which gives new proof of the theorem due to R. T. Whitcomb that the wave drag can be reduced by indenting the body in the region of the wing root. Author emphasizes that this is true only at low supersonic Mach numbers; if Mach number increases, an indented body will always finally cause more total drag of the wing body combination. R. Sauer, Germany

2596. Finston, M., A thin wedge in a slightly non-uniform supersonic flow, *J. Math. Phys.* **34**, 4, 328–334, Jan. 1956.

For the possible measurement of downwash in supersonic flow, author considers a thin wedge in a hypothetical downwash field, computes pressure, and discusses the results. The inclinometer is a thin wedge with pressure taps on both surfaces. The problem is to determine downwash from measured pressures. Analysis superposes solutions to flows with lateral periodicity, a method, author states, that can be applied to other planar problems. Final equation gives the downwash in terms of an integral of the pressure coefficient. Author points out several difficulties with the integration but concludes that this method of separation of lateral variable has definite advantages for some applications. J. DeYoung, USA

2597. Probstein, R. F., The effect of variable fluid properties on the equilibrium laminar boundary layer surface heat transfer rate at hypersonic flight speeds, *AF tech. Rep. WADC TN* 56-2, vii + 19 pp., Dec. 1955.

Author presents an extension of work of Levy [AMR **8**, Rev. 508] and Cohen and Reshotko [AMR **8**, Rev. 2808] for compressible laminar boundary-layer flow. He considers the case where the viscosity and density product is no longer constant and shows that the heat transfer is significantly lower for a realistic variation of fluid properties. A rapid method of estimating this effect is given.

S. Levy, USA

2598. Wade, J. H. T., An experimental investigation of the effect of surface roughness on the drag of a cone-cylinder model at a Mach number of 2.48, *Univ. Toronto Inst. Aerophys. Rep.* no. 34, v + 33 pp. + 3 tables + 32 figs., Sept. 1955.

Experiments were made on a cone-cylinder model (20° included angle of cone) by employing various cylindrical portions having different surface roughness. Skin friction was determined by subtracting direct force measurement on the cone alone from that on the cone-cylinder combination. Roughness scale covered range from 6 to 10,000 microinches. Friction coefficients for smoothest cylinder agreed fairly well with previous similar measurements. Below a roughness of about 900 microinches, no effect of roughness on friction could be detected. Above this critical roughness, the skin friction was markedly affected by roughness height. Critical value is about 30% lower, when comparison is made with fluid properties evaluated at wall temperature, than the corresponding value obtained by Prandtl and Schlichting for incompressible flow. In terms of computed sublayer thickness, critical roughness height is calculated to be about ¼ of the laminar sublayer thickness.

D. R. Chapman, USA

2599. Graham, E. W., Lagerstrom, P. A., Licher, R. M., and Beane, B. J., A theoretical investigation of the drag of generalized aircraft configurations in supersonic flow, *Douglas Aircraft Co. Rep.* no. SM-19181, 121 pp., July 1955.

This is a learned mathematical paper relating to fluid motion. The linearized theory of supersonic airflow is applied to spatial optimum problems. The problem raised is what distribution of either (a) a specified amount of lift or (b) a specified amount of airfoil volume within a definite space portion gives rise to the least drag. The space portions considered for the lift are a sphere, an ellipsoid, and a double Mach cone frustrum. The space portions for the volume distribution include a definite length of a streamline (axis) and a ring.

Many mathematical detail questions related to these problems are aired. More than one hundred pages of double-spaced typewritten pages are devoted to the mathematical discussion and, even then, the discussion appears to be too compressed in some places.

The theoretical drag reduction from a planar distribution (one airfoil) by spreading the lift out spatially (multiple airfoil) is distinct, but not impressive. It will hardly encourage the engineer to consider seriously a multiple-wing arrangement in view of the obvious disadvantage of that arrangement in combination with the additional parasite drag not considered in this paper and to be expected from a multiple-wing arrangement.

M. M. Munk, USA

2600. Hall, J. G., Transition through a contact region, *J. appl. Phys.* **26**, 6, 698–700, June 1955.

Contact region in a shock-tube flow is assumed as an initial step change in temperature and density at constant pressure. For weak transitions, neglect of pressure change, and linearization of the conservation equations yield spatially monotonic temperature and density profiles, with contact region thickening as the square root of time. Experimental results are also described and compared with theory where possible.

G. V. Rao, USA

2601. Aslanov, S. K., Magnitude of the local supersonic zone in the flow of compressible gas around a wedge (in Russian), *Prikl. Mat. Mekh.* **19**, 3, 359–362, 1955.

By analyzing the approximate solution given by J. Cole for transonic flow about a finite wedge [*J. Math. Phys.* **30**, 2, 1951; AMR **4**, Rev. 4527], author establishes expressions in terms of infinite series for the transverse velocity component on sonic line and for the lateral extension of the supersonic region. Numerical results for both of these quantities are given. Author finds further that for sonic flow the hodograph singularity corresponding to infinity of physical plane is of order $v^{-4/3}$ (v transverse velocity component), whereas previous result due to Frankl [*Dokladi Akad. Nauk SSSR (N.S.)* **57**, 1947] had given the exponent −5/3. No explanation of this discrepancy is given.

A. von Baranoff, France

2602. Lomax, H., Fuller, F. B., and Sluder, L., Generalized indicial forces on deforming rectangular wings in supersonic flight, *NACA Rep.* 1230, 27 pp., 1955.

See AMR **8**, Rev. 3147.

2603. Eggers, A. J., Jr., and Savin, R. C., A unified two-dimensional approach to the calculation of three-dimensional hypersonic flows, with application to bodies of revolution, *NACA Rep.* 1249, 27 pp., 1955.

See AMR **6**, Rev. 1958.

2604. Barna, P. S., Some effects of the addition of heat to a one-dimensional high speed air flow, *Aero. Res. Labs., Melbourne, Austral. Rep.* ME 73, 38 pp. + 16 figs., Nov. 1954.

Experimental results are obtained on five arrangements of constant area or diverging pipes with variously located heating areas. Static pressure, stagnation pressure, and Mach number values are given at various positions along the pipe for the various arrangements tested and for various heating rates. The appropriate theory is discussed but only the frictionless theory is compared to the experimental results; and it is shown to be inadequate, as would be expected.

It appears to reviewer that the paper could be the experimental basis for a much more extensive analysis in terms of a theory with friction so as to reduce the experimental results to correlated friction coefficients. Thus the results would be useful in engineering predictions. As presented, only qualitative use can be made of the results.

H. W. Emmons, USA

2605. Romanenko, S. V., Flow of viscous gases in cylindrical pipes with heat exchange in the presence of compression shocks (in Russian), *Zh. tekh. Fiz.* **25**, 6, 1058–1068, June 1955.

Author considers the different states of flow of a viscous gas which enters a cylindrical tube with supersonic velocity, if the walls of the tube are heated. The treatment is one-dimensional and is based upon previously established results for continuous flow under similar conditions, although in the present investigation compression shocks are admitted. As author states, the heating of the walls does not profoundly modify the results known for adiabatic flow subject to viscous forces.

Paper concludes with description of semigraphical method for determination of shock position and other flow characteristics, if the state in the entrance section, the wall temperature, the geometry of the tube, and the exit pressure are given.

A. von Baranoff, France

2606. Syvertson, C. A., and Dennis, D. H., A second-order shock-expansion method applicable to bodies of revolution near zero lift, *NACA TN* 3527, 57 pp., Jan. 1956.

A second-order shock-expansion method applicable to bodies of revolution near zero lift is developed. Expressions defining the pressures on noninclined bodies are derived by the use of characteristics theory in combination with properties of the flow predicted by the generalized shock-expansion method. This result is extended to inclined bodies to obtain expressions for the normal-force and pitching-moment derivatives at zero angle to attack. The method is intended for application under conditions between the ranges of applicability of the second-order potential theory and the generalized shock-expansion method, namely, when the ratio of free-stream Mach number to nose-fineness ratio is in the neighborhood of 1.

From authors' summary by P. F. Maeder, USA

2607. Cabannes, H., Shock wave reflection in two-dimensional nonsteady flow (in French), *ONERA Publ.* no. 80, 29 pp., 1955.

A plane shock wave running into still air ($K = c_p/c_v = 1.4$) meets a wedge (angle 2 ψ) whose plane of symmetry is orthogonal to the wave front. For this phenomenon the case of regular reflection is first treated. It is assumed that the reflected wave is plane in the vicinity of the meeting point; the angle β between oncoming and reflected waves is calculated as function of ψ and Mach number M of the oncoming wave and it is given graphically as β (M) for some selected values of ψ.

above all, the domain of validity for regular reflection is delimited in the ψ, M – plane and it is shown by numerical comparison that the regularly reflected shock wave must always be detached from the leading edge.

Then the equations for Mach reflection are deduced, assuming that, in the vicinity of the triple point of the Mach ramification, the reflected wave has a plane part (forming the angle β with the oncoming wave) and that the triple point runs along a half-ray through the leading edge forming the angle α with the plane of symmetry of the wedge). The task is to determine $\alpha = \alpha(M, \psi)$ and $\beta = \beta(M, \psi)$. This is first done for some special cases: infinitely weak shock ($M \to 1$); infinitely strong shock ($M \to \infty$); orthogonal reflection ($\beta = \pi/2$); stationary reflection ($\beta = \psi$), wedge with infinitely small angle ($\psi \to 0$). With the aid of these special cases and supported by some further considerations, sufficient material is known to plot the functions $\alpha(M, \psi)$ and $\beta(M, \psi)$ as curves versus M with ψ as parameter. The limiting case of transition from regular reflection to Mach reflection appears to be a phenomenon of instability in so far as infinitely small disturbances of Mach number or direction of the oncoming wave may induce finite variations of the flow characteristics. This is studied with a numerical example.

Finally, the flow behind the shock is analytically formulated as a pseudostationary problem (depending only on x/t, y/t; x,y coordinates in the plane of the flow, t time) and a brief discussion is presented.

Paper is a synthesis partly of older and known and partly of new and author's own investigations. All results are deduced from the common source of nonstationary flow theory. H. Behrbohm, Sweden

2608. Chisnell, R. F., The normal motion of a shock wave through a nonuniform one-dimensional medium, *Proc. roy. Soc. Lond. (A)* **1190,** 232, 350–370, Nov. 1955.

Paper deals with motion of shock wave through perfect gas with constant ratio of specific heats, initially at rest with constant pressure, and with monotonically increasing density-distance distribution. Region of continuously varying density is treated as stack of layers of uniform density separated by elementary contact discontinuities. Neglecting square of elementary change in density, change in shock strength is integrated explicitly from these elementary changes.

Description of flow behind shock but ahead of the first or singly reflected wave, which retreats from shock wave, is obtained as function of initial density alone. Effect on flow of "doubly reflected" wave, generated by singly reflected wave, is dependent on initial density distribution. Doubly reflected wave eventually catches the shock and changes shock strength. Evaluation is given for this condition.

Results indicate satisfactory description of flow is obtained when only single and double reflections are considered, even with considerable initial density variation. R. W. Detra, USA

2609. Billington, I. J., and Glass, I. I., On the one-dimensional refraction of a rarefaction wave at a contact surface, *Univ. Toronto Inst. Aerophys. Rep.* no. 31, 21 pp. + 9 tables + 14 figs., Apr. 1955.

A rarefaction wave is always transmitted. Whether the reflected wave is one of rarefaction or compression depends upon the ratio of the internal energies across the contact surface, there being a critical ratio for two given gases; for the critical ratio itself only a Mach wave is reflected and there is no change of strength of the incident wave on transmission. Illustrations of the interaction are given by means of schlieren photographs, hot-wire anemometer traces, and piezo records. Tables of numerical solutions are included for refraction at air-argon, air-helium, and helium-argon contact surfaces. Throughout the paper the term "shock wave" is used for a continuous wave of compression. D. C. Pack, Scotland

2610. Yur'ev, I. M., Calculation of a nozzle (in Russian), *Prikl. Mat. Mekh.* **19,** 1, 103–105, 1955.

Author describes a scheme to calculate approximate flow in transonic region of axisymmetric or symmetrical plane nozzles. The partial differential equation for the potential function ϕ for the difference from sonic velocity is simplified with retention of some second-order terms, in a coordinate system with x-axis along the axis of symmetry and with sonic velocity at the origin. The approximation $\phi = \frac{1}{2}kx^2 + xf_1(y) + \frac{1}{2}(y)$ is introduced, where k is a constant. Then f_1 and f_2 must satisfy a system of ordinary differential equations which can be solved explicitly in terms of elementary transcendental functions in the plane case. In the axisymmetric case, the solution is expressed in terms of logarithms of rapidly convergent power series and quadratures. J. H. Giese, USA

2611. Seibert, O., Trumpfheller, R., and Rogener, H., Theory of discharge of pressure vessels (in German), *Brennstoff-Wärme-Kraft* **7,** 6, 268–272, June 1955.

A theory of discharge of pressure vessels is presented which permits arbitrary fluids and/or vapors to be treated under arbitrary initial conditions, assuming only that the processes are in thermodynamic equilibrium, quasistationary, adiabatic, and frictionless.

General two-phase processes are treated, giving the mass flow through the vessel opening, and the discharge time. The analysis holds for any adiabatic exponent and equation of state.

Detailed results are shown for the water-water vapor system, including both the initial two-phase process and the final single-phase vapor process in a unified analysis.

Paper gives a complete treatment of discharge processes important for technical applications and represents an important addition to current literature. B. W. Augenstein, USA

2612. Liepman, H. P., An analytic method for the design of two-dimensional asymmetric nozzles, *J. aero. Sci.* **22,** 10, 701–709, Oct. 1955.

An asymetrically curved nozzle might be used to continuously vary the Mach number in a wind-tunnel test section by relative translation of the fixed contours.

Using the continuity equation, irrotationality condition, Bernoulli's equation, and a velocity distribution along the initial expansion contour, dependent variables are expanded in powers of the stream function. The patching Mach line is calculated numerically by the Runge-Kutta method and, from this, the flow inclination and Mach number along it. This then gives the recompression contour.

The design Mach number is changed by contour translation with the solution obtained by a perturbation method which converges in a few cycles—compared to the ten or more iterations required in the characteristics method. R. K. Sherburne, USA

2613. Durham, F. P., Thrust characteristics of underexpanded nozzles, *Jet Propulsion* **25,** 12, 696–700, Dec. 1955.

Author presents an analysis of nonisentropic steady adiabatic one-dimensional flow in nozzles. The boundary layer is neglected except as a source of friction, and the specific heat of the gas is constant. Thrust coefficient and ratio of exit area to throat area are expressed as functions of ambient, exit, and inlet pressures, and the ratio of actual local velocity at a given area to the velocity for the same area in isentropic flow. It is also assumed that the velocity ratio remains constant in a given nozzle but may vary from one nozzle to another. Over the range of area ratios from 6 to 1 author's experiments with dry air flowing from a small nozzle finished to 20(300) microin. roughness agree excellently with values calculated for a velocity ratio of 0.98 (0.97). J. H. Giese, USA

2614. Roth, G. L., Factors in selecting valves for compressible flow, *Control Engng.* **2,** 12, 46–53, 124, Dec. 1955.

Author treats a valve as a variable-area orifice for which the familiar compressible flow equations are applied. Several series- and parallel-valve arrangements are discussed. The flow characteristics as a function of valve opening are derived graphically from the characteristics of a linear valve in a system with and without a fixed flow resistance. Departures from the basic linearities are indicated for the 30 and 90-deg butterfly valve, the slide valve, the barrel valve, and the poppet valve. The author concludes that, where a valve is the controlling resistance in a system, a valve with near-linear flow characteristics should probably be used. This characteristic is not important when the system resistance is the controlling factor. In the case of the mixing of two parallel streams, the author also concludes that good flow-regulating characteristics represent uniform changes in flow or temperature, allowing less flow or temperature surge. Paper presents a simple qualitative approach to the determination of characteristics of valves and valve arrangements for flow control. The examples are chosen to illustrate the approach and do not apparently attempt to cover a wide variety of practical control cases. M. A. Santalo, USA

Wave Motion in Fluids

(See also Rev. 2668)

2615. Skalak, R., An extension of the theory of water hammer, *Trans. ASME* **78,** 1, 105–116, Jan. 1956.

The usual theory of water hammer predicts that pressure waves travel without change of shape. In the present paper, author considers also waves traveling in the wall of the pipe (using Flugge's equations with one additional term for the effect of rotatory inertia) and fluid is assumed to be elastic and inviscid, but no assumption is made regarding its motion except that it is small.

Theory developed shows principally that two waves are generated in general: the one of Allievi-Joukowsky type (but the front of which will gradually disperse); the second is essentially a tension in the pipe wall (but the pressure change of this wave is very small).

G. Supino, Italy

2616. Bazzocchi, F., A method of calculating the oleo-shock absorbers and comparison with results of experimental tests (in Italian), *Aerotecnica* **35,** 3, 111–124, June 1955.

2617. Belova, M. N., Compressed air to calm wind waves (in Russian), *Gidrotekh. Stroit.* **24,** 4, 30–33, 1955.

2618. Bretschneider, C. L., and Abramson, H. N., Field investigation of wave energy loss of shallow water ocean waves, Beach Erosion Board, Office, Chief of Engineers, DA/CE TM no. 46, 41 pp., Sept. 1954.

Field measurements of the wave energy loss in shallow water of the Gulf of Mexico were carried out by simultaneously recording waves at two offshore platforms. From the corresponding values of the significant waves measured at the two platforms, the percentage of reduction in wave energy was determined, from which the bottom friction factors were computed. Percolation losses were neglected in the analysis, since the bottom consists of nonpermeable, fine sediments. The apparent friction factors determined appear to be relatively high, and an explanation was sought in the fluctuation of the bottom, due to extreme nonrigid condition. Theoretical consideration suggests that wave energy loss due to bottom fluctuation is comparable to that due to percolation of a rigid permeable bottom. This latter investigation was only tentative.

J. K. Lunde, Norway

2619. Brillouin, J., Structure of progressive waves (in French), *ONERA NT* no. 30, 44 pp., 1956.

Author discusses behavior of smallish progressive wave motions in compressible fluid giving rise to regions of discontinuity. From the carefully stated hypothesis it is shown that there are two elementary wave types into which more complex acoustic disturbances can be resolved. The properties of these two wave types are considered in detail, and further examples of a more general nature are examined.

G. Power, England

2620. Gerber, R., On a class of solution of equations of motion of a liquid with free surface (in French), *C. R. Acad. Sci. Paris* **242,** 10, 1260–1262, Mar. 1956.

An existence theorem for the steady two-dimensional flow (under gravity) of an incompressible and inviscid fluid in an open channel, possessing a (spacewise) periodic bed, was established by the author in an earlier paper [*J. Math. pures. appl.* **34,** 185–299, 1955]. In the present note he removes a restriction, which was found necessary in the earlier paper, on the permissible values of the slope of the free surface.

The paper is of interest to mathematicians only.

L. C. Woods, Australia

Turbulence, Boundary Layer, etc.

(See also Revs. 2557, 2565, 2571, 2673, 2714, 2715)

2621. Probstein, R. F., and Elliott, D., The transverse curvature effect in compressible axially symmetric laminar boundary-layer flow, *J. aero. Sci.* **23,** 3, 208–224, 236, Mar. 1956.

If, for an axially symmetric boundary layer of thickness Δ, $\Delta/r_0(x)$ is small where $r_0(x)$ is the body radius at a distance x downstream of the nose, it was shown by Mangler that the equations may be reduced to a two-dimensional form. Authors generalize both this transformation and the energy integrals to simplify the equations when Δ/r_0 is of the order of unity. The additional terms that arise are interpreted by them as a favorable pressure gradient. A family of "similar" solutions (i.e., dependent on ordinary differential equations) of these equations is found. In perhaps the most realistic case when $dr_0/dx \ll 1$, the shape of the bodies is $r_0 \propto x^n$ and there is one similar profile for each positive value of n. Finally, there is a discussion of the effect of the additional terms on the boundary layers on a core, in which Δ/r_0 decreases as x increases, and on the circular cylinder in which Δ/r_0 increases with x.

For a more complete discussion of the incompressible boundary layer on the circular cylinder, reference may be made to papers by Lighthill and Glauert [AMR **9,** Rev. 216], Mark [Cal. Inst. Technol. thesis 1954], and the reviewer [AMR **9,** Rev. 817].

K. Stewartson, England

2622. Wilson, W. E., Design of optimum clearances in positive-displacement pumps and motors, *Trans. ASME* **78,** 1, 117–122, Jan. 1956.

The slip flow and drag on moving elements of a positive displacement pump are determined with laminar boundary-layer theory, taking into consideration the internal heating of the liquid and consequent change in viscosity. The optimum clearance, under various operating conditions, is determined. In reviewer's opinion, the energy considerations in this paper are confused. Also the expression for the flow rate through the clearance cannot be correct because it would tend to infinity with vanishing viscosity. This is due to the fact that no allowance has been made for separated flows.

H. G. Loos, USA

2623. Huber, P. W., and McFarland, D. R., Boundary-layer growth and shock attenuation in a shock tube with roughness, *NACA TN* 3627, 49 pp., Mar. 1956.

Boundary-layer velocity profiles were determined by firing bullets upstream along the axis of the shock tube and measuring, on schlieren photographs, the bow wave angle at points in the boundary layer. The artificial roughness consisted of continuous rows of pyramid-shaped elements oriented at 45° to the flow direction.

The velocity profiles were compared with steady-flow experiments by Moore (unpublished), who used lateral square-bar roughness, and by Klebanoff and Diehl [AMR **5,** Rev. 1496], who used sand roughness, and with Schlichting's flat-plate steady-flow sand-roughness theory. The measurements of over-all boundary-layer thickness were in good agreement with other experimental results and with theory. The velocity profiles were somewhat less full for the pyramid and lateral-bar data than for the sand-roughness experiments. All experimental profiles were considerably less full than predicted by the Schlichting theory. This causes only small differences in momentum thickness but leads to large differences in displacement thickness.

Shock-wave attenuation was measured both for smooth walls and for artificial roughness and compared with a simple theory which assumes that mass flow decrement due to the boundary-layer displacement thickness at the entropy discontinuity is equal to the shock-mass-flow decrement at the same time. The displacement thickness was found from flat-plate steady-flow theory. Measured attenuation agreed reasonably well with theoretical values for small displacement thicknesses but was considerably lower than predicted by theory at the higher values of the displacement thickness.

N. H. Johannesen, England

2624. Morduchow, M., Laminar separation over a transpiration-cooled surface in compressible flow, *NACA TN* 3559, 32 pp., Dec. 1955.

A theoretical analysis of laminar separation in compressible flow over a transpiration-cooled surface maintained at a uniform wall temperature is made. A simple method of calculating the separation point over such a surface for a given adverse pressure gradient, Mach number, wall temperature, and uniform coolant temperature is developed. This method is expected to be sufficiently accurate for most practical purposes. To show the effects of these parameters on the separation point, a numerical example is worked out in detail. The normal mass flow is found to have a predominating effect on the location of the separation point, since over a transpiration-cooled wall separation is found to occur upstream of the separation point over a heat-insulated wall without normal

mass flow at the same adverse pressure gradient and Mach number. The method of analysis is based on an application of the von Karman momentum integral equation in conjunction with seventh-degree velocity and stagnation-enthalpy profiles.

From author's summary by L. Talbot, USA

2625. Bam-Zelikovich, G. M., Calculation of boundary-layer separation (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 12, 68–85, Dec. 1954.

Paper begins with critical review of application of momentum integral equation and of mixing length theory to calculation of separation for turbulent boundary layer, particularly for high-speed flow and in presence of large pressure gradients. Noting frequent agreement between experiment and such calculations, author supposes that success is due to a skillful choice of empirical constants rather than to the merits of one or another theory of turbulent flow. To strengthen this view author quotes remarkable result obtained by S. Kaplun [ZAMP **5**, 1954] for laminar flow, namely, the independence of skin friction, but the essential dependence of velocity profile, on system of coordinates in which boundary-layer simplifications are performed. Paper sets out to derive theory of turbulent (and also laminar) separation which would be independent of any theory of turbulence and of the choice of velocity profile, would be based on more general hypotheses, and would contain a small number of empirical constants. The fundamental assumption is that the flow at a given cross section in the boundary layer is affected only by the external flow in its immediate neighborhood.

By an argument of a dimensional nature, author derives interesting criteria for separation in laminar and turbulent flow and presents them in terms of a series in a characteristic parameter with Mach-number-dependent coefficients. For example, at zero Mach number, turbulent separation is given by $p'_x\delta^*/\rho U^2 = 0.015$ or $p'_x\delta^{**}/\rho U^2 = 0.05$, with usual notation ($p'_x$ streamwise gradient). At non-zero Mach number, constants are replaced by functions of Mach number. In laminar case $p'_x\delta^*/\mu U = \varphi_1(M)$. Analogous expressions for rate of growth of displacement (or momentum) thickness are derived. The displacement thickness at separation is given by $\delta^*_{sep} = \frac{1}{3} \times Re^{-\frac{1}{5}}$.

Method is applied to discussion of problem of shortest nonseparating diffuser, and to analysis of problem of separation in presence of incident shock wave.

J. Kestin, USA

2626. Morton, B. R., Taylor, G., and Turner, J. S., Turbulent gravitational convection from maintained and instantaneous sources, *Proc. roy. Soc. Lond.* (A) **234,** 1196, 1–23, Jan. 1956.

Paper gives theoretical basis for predicting final height to which a plume of light fluid will rise in a stably stratified fluid. Analysis is general and applies to any variation of density with height. Equation as developed assumes: (1) That profiles of vertical velocity and buoyancy are similar at all heights; (2) that the rate of entrainment of fluid at any height is proportional to a characteristic velocity at that height; and (3) that the fluids are incompressible and do not change volume on mixing. The case of an instantaneous source of buoyancy yields an exact solution. Analysis is applied to the atmosphere and results obtained appear to conform with observations.

J. M. DallaValle, USA

2627. Ghosh, K. M., Numerical solutions to find out spectrum function of isotropic turbulence with a fourth power law fitting at small eddy numbers, *Bull. Calcutta math. Soc.* **47,** 2, 71–75, June 1955.

A nonlinear differential equation occurring in the statistical theory of turbulence is integrated for two particular cases.

W. Squire, USA

2628. Monin, A. S., Equations of turbulent diffusion (in Russian), *Dokladi Akad. Nauk SSSR (N.S.)* **105,** 2, 256–259, 1955 (translated from Russian by M. D. Friedman, 572 California St., Newtonville, Mass., 6 pp.).

The problem of diffusion with variable coefficient is studied. Instead of using the classical diffusion equation, author considers the diffusion equation in the form of Fourier transform with a diffusion coefficient proportional to the $-4/3$ power of the wave number. This power is written in accordance with the Kolmogoroff theory of locally isotropic turbulence. Solution is obtained for an arbitrary initial distribution of the concentration in the case of a spherical symmetry. In particular, when the initial distribution is a point source, two identical forms of solutions are given: in the integral form of Bessel functions and in the form of the Whittaker confluent hypergeometric function. As a result the concentration varies as $t - 3$ at the center of the turbulent diffusing cloud, where t is the interval of time. At great distances r from the source, the concentration varies as $tr^{-4/3}$. This indicates that the turbulent diffusion reaches farther than the molecular diffusion in view of the coarser vortexes becoming more effective as the size of the diffusing cloud increases.

Author does not make any specific distinction between various modes of turbulent diffusion: momentum, heat, or matter.

C. M. Tchen, USA

2629. Weske, J. R., The effect of stretching of a vortex cone, *Inst. Fluid Dynam. appl. Math., Univ. Maryland TN* BN-57, 20 pp., Aug. 1955.

Author presents some theoretical considerations believed to be pertinent to the mechanism of generation of "horseshoe vortexes." The core of a straight vortex—simplified by assuming definite radius within which rotation is initially constant, and this core surrounded by an irrotational vortex field—is thought stretched by some cause or other. Neglecting viscosity and compressibility in this vortex model, the state of flow in a cross section of the core after stretching is determined from the state of flow before stretching. For convergence of vortex core beyond a certain core-radius ratio, author's results give axial backflow in the center of the core area, and radially unstable flow just outside of this central area. A simple experiment in which a body of fluid of constant rotation passes through an orifice shows that, under proper conditions, backflow actually can occur.

H. Görtler, Germany

2630. Kovásznay, L. S. G., Development of turbulence-measuring equipment, *NACA Rep.* 1209, 30 pp., 1954.

See AMR **6,** Rev. 3198.

Aerodynamics of Flight; Wind Forces

(See also Revs. 2437, 2456, 2576, 2581, 2584, 2585, 2586, 2588, 2589, 2590, 2593, 2594, 2599, 2606, 2677, 2680, 2681, 2682)

2631. Hamilton, J. A., and Hufton, P. A., Free flight techniques for high speed aerodynamic research, *J. roy. aero. Soc.* **60,** 543, 151–185, Mar. 1956.

The development rocket-borne and rocket-launched high-speed airplane model test is described. Details of airborne components, telemetering units, tracking, and their calibration are also discussed. Tests on controls, drag measurements, longitudinal stability evaluations, lift measurements, pressure measurements, aeroelastic estimations, and sonic bang recordings are effected. The Reynolds numbers involved are much higher than are usual in the wind tunnel, and extensions of Mach numbers are obtained beyond the tunnel limits, both free of the tunnel wall interference.

M. Sanuki, Japan

2632. Kaufmann, W., Calculation of the circulation distribution in plane incompressible flow around thin airfoils (in German), *Z. Flugwiss.* **3,** 11, 373–376, Nov. 1955.

The method of calculating the chordwise circulation distribution of a thin airfoil section with small camber in incompressible flow has been introduced by Birnbaum and Glauert, replacing the airfoil by the mean line. This paper proposes a new method of solving this problem by applying Multhopp's formula of interpolation which is used for the determination of the spanwise lift distribution of a wing of finite span The circulation distribution is obtained from a set of linear equations derived from the boundary conditions at the various points on the chord. The values of eight coefficients in the series expressing the circulation distribution are shown in a table. Reviewer believes that this method is simpler than existing methods.

T. Okamoto, Japan

2633. Goodman, A., and Thomas, D. F., Jr., Effects of wing position and fuselage size on the low-speed static and rolling stability characteristics of a delta-wing model, *NACA Rep.* 1224, 31 pp., 1955.

See AMR **8,** Rev. 120.

2634. Pian, T. H. H., and Ashely, H., A study of gust entry of swept-back wings, *Proc. second U. S. nat. Congr. appl. Mech.*, June 1954; Amer. Soc. mech. Engrs., 1955, 755–762.

Paper starts with a strip theory for swept wings of finite aspect ratio penetrating a sharp-edged gust. Küssner's lift growth function is expressed both by Jones' exponential function and by a polynomial approximation devised by Codik, Lin, and Pian. The total lift rise versus the nondimensional gust penetration distance is presented in general formulas and in curves.

The main part derives a "semi-three-dimensional" theory for incompressible flow. For the case of a wing with constant chord and infinite aspect ratio, the gust front passing over the wing can be converted into a stationary angle-of-attack discontinuity, if the wing is turned 90° and if a suitable speed component in span direction is added. Tapered wings are treated by letting the chord length vary with time and integrating at each instant over the wing span.

The "semi-three-dimensional" theory gives a more rapid rise of the lift than the strip theory. This indicates that the latter is on the unconservative side. Modifications for cases of subsonic (subcritical) and supersonic (supersonic and subsonic leading edge) are discussed. Application of the new theory to the gust response of an aircraft gives higher maximum accelerations and a faster response than strip theory.

G. W. Braun, USA

2635. McDevitt, J. B., and Haire, W. M., Investigation at high subsonic speeds of a body-contouring method for alleviating the adverse interference at the root of a sweptback wing, *NACA TN* 3672, 38 pp., Apr. 1956.

An experimental investigation was made of a body contouring method for alleviating at subsonic speeds the adverse interference at the root of a 35° sweptback wing in combination with various bodies. Modifying the body shape did not significantly affect the aerodynamic characteristics at subcritical speeds. At Mach numbers above the critical, improved aerodynamic characteristics were evidenced by large reductions of drag, an increase in lift-curve slope, and a reduced change of pitching-moment-curve slope with increasing Mach number.

From authors' summary

2636. Glauert, M. B., The application of the exact method of aerofoil design, *Aero. Res. Counc. Lond. Rep. Mem.* no. 2683, 45 pp., 1955.

In 1945, Lighthill published a method of determining the coordinates of an airfoil when the velocity distribution is specified. As implied by the title, this report is concerned with the detailed application of Lighthill's method. The appendixes of this report contain not only useful formulas and tabulated functions which will aid the designer but also a practical example of the use of the method.

The method is flexible, including not only standard airfoils but also airfoils with suction. In the opinion of the reviewer the latter application should cause the method to be of increasing importance.

E. E. Covert, USA

2637. Huston, W. B., and Skopinski, T. H., Measurement and analysis of wing and tail buffeting loads on a fighter airplane, *NACA Rep.* 1219, 27 pp., 1955.

See AMR **7**, Rev. 3980.

2638. Furlong, G. C., and Bollech, T. V., Effect of ground interference on the aerodynamic and flow characteristics of a 42° sweptback wing at Reynolds numbers up to 6.8 × 10⁶, *NACA Rep.* 1218, 60 pp., 1955.

See AMR **5**, Rev. 1178.

2639. Spreiter, J. R., and Alksne, A., Theoretical prediction of pressure distributions on nonlifting airfoils at high subsonic speeds, *NACA Rep.* 1217, 42 pp., 1955.

See AMR **7**, Rev. 3630.

2640. Tobak, M., On the use of the indicial function concept in the analysis of unsteady motions of wings and wingtail combinations, *NACA Rep.* 1188, 43 pp., 1954.

The concept of indicial aerodynamic functions is applied to the analysis of the short-period pitching mode of aircraft. By the use of simple physical relationships associated with the indicial-function concept, qualitative studies are made of the separate effects on the damping in pitch of changes in Mach number, aspect ratio, planform shape, and frequency. The concept is further shown to be of value in depicting physically the induced effects on a tail surface which follows in the wake of a starting forward surface. Considerable effort is devoted to the development of theoretical techniques whereby the transient response in lift at the tail to the wing wake may be estimated. Numerical results for several representative cases are presented, and these are analyzed to reassess the importance of the contribution to the rotary damping moment of the interference lift at the tail.

From author's summary by W. P. Jones, England

2641. Biot, M. A., The divergence of supersonic wings including chordwise bending, *J. aero. Sci.* **23**, 3, 237–251, 271, Mar. 1956.

This paper was previously published as *Calif. aero. Lab. Rep.* no 67. It is a complete theoretical treatment of supersonic wing chordwise divergence and may well be used as a basis for further work, both theoretical and experimental, to verify the seriousness of this problem.

J. E. Stevens, USA

2642. Welsh, C. J., Results of a flight investigation to determine the zero-lift drag characteristics of a 60° delta wing with NACA 65-006 airfoil section and various double-wedge sections at Mach numbers from 0.7 to 1.6, *NACA TN* 3650, 13 pp., Apr. 1956.

Results of an exploratory free-flight investigation at zero lift of several rocket-powered drag-research models equipped with 60° sweptback delta wings are presented for a Mach number range from about 0.7 to 1.60. The airfoil sections tested included the NACA 65-006 and a series of double-wedge sections with various positions of maximum thickness.

From author's summary

2643. Anderson, S. B., and Bray, R. S., A flight evaluation of the longitudinal stability characteristics associated with the pitch-up of a swept-wing airplane in maneuvering flight at transonic speeds, *NACA Rep.* 1237, 12 pp., 1955.

Flight measurements on a sweptwing jet aircraft showed that the pitch-up encountered in a wind-up turn at transonic Mach numbers was due principally to an unstable break in the wing pitching moment associated with flow separation near the wing tip. The pitch-up encountered in slowing down in a dive-recovery maneuver was due chiefly to a reduction in wing-fuselage stability. An increase in down load for the horizontal tail was indicated with increase in Mach number for normal force-coefficient values in excess of approximately 0.2.

From authors' summary

2644. Holder, D. W., Note on the flow near the tail of a two-dimensional aerofoil moving at a free-stream Mach number close to unity, *Aero. Res. Counc. Lond. curr. Pap.* no. 188, 5 pp. + 6 figs., 1955.

This note discusses the flow near the trailing edge of a two-dimensional airfoil moving at a free-stream Mach number close to unity, for cases where the effects of viscosity are small A qualitative argument, which is supported by experimental evidence, suggests that the local Mach number downstream of the trailing-edge shock waves is approximately independent of free-stream Mach number, airfoil geometry, and incidence. It follows from this result that there is a unique relationship between the flow deflection angle at the trailing edge and the local Mach number just upstream of the trailing-edge shock waves. This relationship is determined by using results obtained during wind-tunnel experiments on airfoils of the R.A.E. series, and may sometimes be used to give rapid estimates of the local Mach number at the trailing edge of an airfoil in terms of the trailing-edge angle, incidence, and control angle. When the Mach number immediately ahead of the trailing-edge shock has been determined, the local Mach numbers over the surface ahead of the trailing edge can be estimated by using simple-wave theory. The characteristics of straight-sided controls are considered as an example.

From author's summary

2645. Salter, C., and Jones, R., Tests on a swept-back wing and body with endplates and wing tip tanks in the compressed air tunnel; Appendix, Weber, J., Comparison between the measured lift and drag and calculated values for the wing with tip tanks, *Aero. Res. Counc. Lond. curr. Pap.* no. 196, 18 pp. + 7 figs., 1954.

Results are given of experiments carried out to determine the effect,

in respect of lift, drag and pitching moment, of wing tip tanks and of two sizes of endplates on the tapered swept wing model already examined and described in AMR **7**, Rev. 4005.

The tests were undertaken primarily in order to extend the range of R for checks on the theoretical considerations of AMR **6**, Rev. 2596.

As regards lift and pitching moment, the effects are found to be fairly well defined. The drag characteristics are, however, less consistent, but it appears that endplates have the effect of reducing the drag of the model over quite a large range of C_L. This does not apply in the case of wing tip tanks. From authors' summary

2646. Williams, J., An analysis of aerodynamic data on blowing over trailing edge flaps for increasing lift, *Aero. Res. Counc. Lond. curr. Pap.* no. 209, 17 pp. + 13 figs., 1955.

Results of many tests are analyzed. Increased blowing increases the lift until theoretical (potential) lift is achieved; with higher blowing rates the lift still increases but more slowly. It is found that the blowing momentum coefficient is a better parameter than the blowing quantity coefficient. An attempt is made to give universal results for two dimensions, with the claim that though there is scatter the curves should be adequate in practice. Formulas are given for converting the results for finite straight wings, and it is suggested that, for sweptback wings, the straight-wing lift increase must be multiplied by cos (angle of sweep-back of hinge line), though this conclusion is only tentative.

Changes in moment coefficient are given, but it was found that changes in stalling angle were not consistent enough to be of use.

A useful statement of present information; the types of further experimentation necessary are clearly stated.

J. C. Cooke, British Malaya

2647. Luskin, H., and Klein, H., The influence of turbojet airflow on the aerodynamic design of airplanes, *Douglas Aircr. Co. Rep.* SM-19111, 42 pp., June 1955.

2648. Gabrielli, G., A new, general analytic expression for aircraft polars (in Italian), *Aerotecnica* **35**, 3, 125-128, June 1955.

Generalized approximation $C_D = K_1 + K_2\ C_L{}^n$ is proposed for use in simplified calculations of high-speed performance in same manner as parabolic polar approximation is often used in low-speed domain. Unfortunately, in using this relation (as, e.g., in determination of flight speed for minimum drag), author takes no account of fact that K_1, K_2, and n are themselves functions of Mach number.

J. V. Foa, USA

2649. Nicolaides, J. D., and MacAllister, L. C., A review of aeroballistic range research on winged and/or finned missiles, Bur. Ord., Dept. of Navy, Wash., D. C., Ballistic TN no. 5, 15 pp. + 17 figs., 1955.

A serious problem in proper design of guided and unguided rockets is evaluation of the variety of aerodynamic coefficients which define flight and response characteristics. In a very complete treatment, authors, beginning with an outline of pertinent equations of motion, apply flight data obtained in aeroballistic range for several simple finned configurations to the framework of theory and obtain experimental values of the aerodynamic coefficients.

Range flight data correspond to a variety of dynamic situations such that consideration can be given to conditions of pure rolling motion, pure pitching and yawing motion, pitching, yawing and steady rolling motion, etc. Data are obtained in the speed range of Mach 1 to 3.

Probably the most significant aspect of the work is use of analog computer as a simulator in fitting the data to theory to obtain aerodynamic coefficients. It is found that the data ably fit a tricyclic theory of motion under a wide variety of conditions.

W. W. Berning, USA

2650. Monaghan, R. J., and Crewe, P. R., Formulae for estimating the forces in seaplane-water impacts without rotation or chine immersion, *Aero. Res. Counc. Lond. Rep. Mem.* no. 2804, 28 pp., 1955.

The report contains design formulas and curves for estimating the maximum forces, together with the times and drafts associated with these forces, in main-step landings of seaplanes provided there is neither rotation nor chine immersion. Good agreement is found with the results of model tests made under controlled conditions.

The basic formulas and curves presented are considered to be the most satisfactory and accurate of the many proposed in recent years. They involve the use of a new basic parameter $(1/y_o)$ which is a measure of the effect of forward velocity; a new formula for associated mass, $\frac{1}{4}(\text{area})^2/\text{perimeter}$, and a new method of plotting which is considered to be the most useful for the analysis of experimental data. The first is defined by $1/y_o = V_T \tan \tau/V_{n0}$ if V_T is constant $1/-y_o = V_H \sin \tau/V_{n0}$, if V_n is constant where τ is the attitude, V_{n0} is the velocity component normal to the keel at first impact, V_T and V_H are the velocity components parallel to the keel and undisturbed water surface respectively. From authors' summary

2651. Ridland, D. M., Friswell, J. K., and Kurn, A. G., Investigation of high length/beam ratio seaplane hulls with high beam loadings. Hydrodynamic stability, Part I; Techniques and presentation of results of model tests, *Aero. Res. Counc. Lond. curr. Pap.* no. 201, 27 pp. + 26 figs., 1955.

This report aims at providing a background, in conjunction with the individual model test reports, to the hydrodynamic stability side of a research program on seaplanes with high length/beam ratio hulls and high beam loadings.

Methods of testing and presenting results, which will be used throughout the program, are described and points requiring further investigation are noted. From authors' summary

2652. Parker, R., A survey of scale effects on the hydrodynamic testing of seaplane models, *Aero. Res. Counc. Lond. curr. Pap.* no. 179, 20 pp. + 4 figs., 1954.

A general survey is made of all the factors where true-dynamic similarity cannot be achieved in model tests of seaplane hulls and the likely effects on test results are discussed with reference to towing tank models and medium-size research aircraft.

In resistance tests, the correction for Reynolds number effects requires more investigation, and the artificial production of a turbulent boundary layer is the most likely means of achieving the required improvement in accuracy.

Pressure effects are likely to affect the break away of flow at small discontinuities such as extreme fairings with resultant errors in both stability and resistance test results. More accurate and systematic full-scale data than at present available is needed before methods of allowing for this can be satisfactorily developed.

From author's summary

2653. Parker, R., A note on the development of sensitive pressure operated water contacts for use on seaplanes, *Aero. Res. Counc. Lond. curr. Pap.* no. 176. 7 pp. + 4 figs.. 1954.

A pressure-operated water contact has been developed, suitable for indicating the instants of take-off and touch-down for a seaplane hull. Flight tests have shown that the instrument is accurate in operation and sufficiently robust for normal flight test use.

From author's summary

2654. Harper, D. J., The influence of rolling moments on spin recovery as observed in model-spinning tests, *Aero. Res. Counc. Lond. Rep. Mem.* no. 2831, 13 pp., 1954.

Several aspects of model-spinning test technique have been brought into prominence by recent full-scale developments. Correlation between model and full-scale recoveries has been poor in some cases, and it appears from model tests of some new aircraft that full-scale recovery may depend on other means in addition to the normal use of rudder and elevator.

Analysis of model data shows the effects of applied rolling moments and of aileron deflections on both spin and recovery to be closely related to the distribution of loading in the aircraft. The ordinary model test result can be considerably in error in either direction due to the neglect of probable scale effects on rolling moments.

Deflection of the ailerons can be of great assistance to model recovery, and flight confirmation of this effect is required. Information on the scale effects on rolling moments for delta aircraft is also urgently needed, as these models show much greater sensitivity than conventional models to the application of rolling moments.

From author's summary

Aeroelasticity (Flutter, Divergence, etc.)

(See Revs. 2631, 2637, 2641)

Propellers, Fans, Turbines, Pumps, etc.

(See also Revs. 2436, 2459, 2535, 2561, 2575, 2594, 2613, 2649, 2697, 2727, 2737, 2749, 2751)

2655. Khanin, G. A., Certain questions on the aerodynamic investigation of the auxiliary elements of the axial compressor stages of turbines (in Russian), *Teploenergetika* **2,** 1, 12–17, 1955 (translated from Russian by M. D. Friedman, 572 California St., Newtonville, Mass., 12 pp.)

The effect on the flow efficiency of various aerodynamic shapes of bypass ducts in axial compressor turbines and of the flow configuration at the inlet of these ducts were investigated. The experiments were conducted on three models having different tube diameters, with steam as the test fluid. Power losses and loss coefficients are calculated from the experimental results and given in the form of tables. Also, some graphs of the static pressure distributions at the nozzle are given.

It is concluded that the experiments show clearly the feasibility and the need for careful designing of the bypass elements in compressors and turbines.

Reviewer believes that the paper does not contribute anything new, but does confirm some long established facts. Also, the English translation leaves much to be desired and has to be treated with caution.

K. Pilarczyk, USA

2656. Collins, D. F., and Thomas, D. W., A comparison of the total weight and bulk of in-line naval gas turbine engines of differing degrees of complexity, *Inter. Shipbldg. Progr.* **3,** 17, 25–36, Jan. 1956.

The effect is investigated of progressively increasing the complexity of gas-turbine engines for naval application. The bases of comparison are: the weight and bulk of the plant plus the fuel for a given operating schedule, plant layout in a typical ship, and size of deck openings.

The weights and sizes of each of the four basic power plants considered are estimated from detailed design studies. Each complete power plant consists of a cruising and a boosting engine, and, where possible, the engine components form in-line arrangements. An operating schedule of the ship is taken which is typical of medium-sized naval vessels.

It is concluded that, of the plants considered, the double-compound intercooled plant with heat exchange used on the cruising engine yields the least value of (plant plus fuel) weight, and size of deck openings. The single-compressor-engined plant gives the shortest machinery length, though this plant is among the worst as regards over-all bulk and size of deck openings.

Of the double-compound-engined plants considered, that without intercooling and heat exchange is the worst as regards total weight, bulk, and size of deck openings. From authors' summary

2657. Pavia, R. V., An accurate calibration of a Derwent 8 gas turbine, *Aero. Res. Lab. Melbourne, Austral.*, ME *Note* no. 202, 12 pp. + 4 tables + 4 figs., Aug. 1955.

2658. Boeker, G. F., and Sternlicht, B., Investigation of translatory fluid whirl in vertical machines, *Trans. ASME* **78,** 1, 13–19, Jan. 1956.

See AMR **8,** Rev. 894.

2659. Makeev, G. S., and Shal'nev, K. K., Hydraulic protection of turbines from cavitation erosion (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 11, 87–104, Nov. 1954.

This is a very interesting paper; it describes experiments performed on full-size turbines. Results of laboratory experiments obtained by K. K. Shal'nev, which show that intensity of cavitation depends on shape of profiles of peripheral edge of propeller turbine blades, were applied in practice.

Rounded off inlet edge of blades' peripheral edge reduces cavitation, and consequently less erosion was observed on the throat ring. Although no data are given, authors claim that this simple and small change is very effective in preserving turbine blades.

W. B. Palijenko, Canada

2660. Abramovich, S. F., and Zhukovskiĭ, M. I., Graphic method for the calculation of flow around turbomachine profiles (in Russian), *Inzhener. Sbornik, Akad. Nauk SSSR* no. 20, 13–20, 1954.

Graphic methods for computation of flow around profiles, as proposed by S. F. Abramovich [title source no. 11, 1950], are based on the use of a network of stream lines and isopotential lines. In the present paper a graphic method is given which is based on a somewhat simpler mapping function than that used by Abramovich. The method is illustrated by an example. E. Leimanis, Canada

2661. Schüffler, H., Investigations on a radial centrifugal pump with different rotor diameters (in German), *Maschinenbau-Technik* **5,** 2, 79–85, Feb. 1956.

Common practice with stock series of centrifugal pumps is to adjust for intermediate conditions by turning down impellers. Author has carried out tests on a stock pump rated at $H = 40$ m, $Q = 100$ m³/hr at 1450 rpm, the runner being initially 349 mm diameter and turned down finally to 220 mm. Ten different diameters, not equally spaced, were tested.

Effects of varying diameter on head, discharge, and efficiency at normal speed of 1450 rpm are shown by graphs. Effects on various losses and on cavitation limits are also analyzed.

Useful results are that best efficiency is approximately constant at 80% for diameters from 330 to 270 mm, falling to 76% for 349 mm, and to 70% for 220 mm, and that onset of cavitation occurred at suction head 8.1–8.4 m for all diameters.

Author concludes that at best efficiency point effect of reducing diameter from D_2 to D_2' is approximately $H'/H = (D_2'/D_2)^2$ and $Q'/Q = (D_2'/D_2)^{3/2}$.

Reviewer considers results could have been better presented. More details of pump could have been given; e.g., runner blade angles, inlet diameter, and exit width. Dimensionless plotting could have been more freely used. No information on accuracy of tests is given.

A. Burn, Australia

2662. Hutton, S. P., Component losses in Kaplan turbines and the prediction of efficiency from model tests, *Proc. Instn. mech. Engrs.* **168,** 28, 743–762, 1954.

Paper is attempt to provide improved formula for estimating Kaplan turbine efficiencies from model tests. An excellent historical and critical review is given of existing formulas, including those of Moody. Theoretical analysis assumes that losses in runner and draft tube are divided into frictional and kinetic losses, with only the former varying with model scale. Resulting formula gives results between those of Moody and Ackeret, and author gives test results to verify his equation. An attempt is made to predict efficiencies at other than optimum conditions.

Read together with the excellent discussions, the paper is extremely valuable for those in this field. D. G. Huber, Canada

2663. Hydraulic Prime Movers Committee, Hydraulic Div., ASME, Recent progress in hydraulic prime movers, *Mech. Engng., N. Y.* **77,** 11, 975–982, Nov. 1955.

Although the hydraulic turbine industry is more than 100 years old, there has been considerable progress in technological and mechanical features of hydraulic prime movers and their auxiliaries during the past few years. Reports regarding such progress have been obtained from some of the manufacturers and form the basis of this review.

From summary

2664. Dollin, F., Factors influencing the continuing development of the steam turbine, Instn. mech. Engrs., Preprint 3–12, 1954.

2665. Savinskiĭ, K. A., Distribution of concentrations of gas in stream-jet vacuum pump (in Russian), *Zh. tekh. Fiz.* **24,** 5, 875–878, May 1954.

2666. Abramson, B. N., Brandwein, D. S., and Menes, H. C., The 350,000-pound thrust rocket test stand at Lake Denmark, N. J., *Jet Propulsion* **24,** 5, 291–296, Sept./Oct. 1954.

2667. Isay, H., Flow through a Voith-Schneider propeller with small advance ratio (in German), *Ing.-Arch.* **23,** 6, 379–401, 1955.

Paper treats incompressible flow through rotating Voith-Schneider propeller. Velocity fields due to bound and shed vortexes are calculated for a 6-bladed propeller. Boundary conditions for resultant integral equation are developed. The integral equation is solved by approximation methods where the circulation distribution is expressed as a Fourier polynomial and an iteration procedure is used whose convergence is demonstrated.

A detailed numerical example is computed, showing the convergence of the iteration process. The resultant propeller forces are calculated using the Kutta-Joukowsky theorem. Finally, the angle-of-attack program around the propeller periphery is calculated which gives a net force directly forward into the stream.

The detailed and careful nature of this paper will make it a very useful addition to current propeller literature.

B. W. Augenstein, USA

2668. **Benson, R. S., The effect of excess scavenge air on the pressure drop in the cylinder of a two-stroke cycle engine during exhaust blowdown,** *J. roy. aero. Soc.* **59,** 773–778, Nov. 1955.

Pressure-time histories in an engine cylinder and exhaust pipe are calculated to compare the exhaust blowdown process in a running engine with that in a model. In the former case, with excess scavenge air, the exhaust pipe gas is cooler and denser than that in the cylinder, leading to reflection of pressure waves at the boundary between hot and cold gas, whereas in the latter case no such reflection occurs. Reflections from the exhaust-pipe end are neglected. Four cases are considered: excess scavenge air (1) with and (2) without interface reflection; (3) constant temperature; and (4) no exhaust pipe. With an initial pressure of 5 atmos abs, the cylinder pressure after 30° crank angle (exhaust valve just fully open) falls to (1) 1.65, (2) 1.35, (3) 1.15, (4) 1.0 atmos abs, indicating that reflection effects may be serious.

Calculations are made by the method of characteristics which can be integrated in the case when interface reflections are neglected and boundary conditions are expressed graphically for ease of calculation. Unfortunately, the basic theoretical equations have been condensed at the expense of clarity and the continuity boundary equation is obscure. Derivation of this equation and use of the boundary chart is apparently to be published elsewhere.

D. G. Stewart, Australia

2669. **Williams, C. G., Some experiences of automobile research,** Instn. mech. Engrs., Preprint, 18 pp., 1955.

Book—2670. **Anonymous, Escher Wyss 1805–1955, 150 years of development,** Zürich, Escher Wyss, Ltd., 1955, 246 pp.

Published in the Jubilee Year, this work replaces Vol. 27/28 of the *Escher Wyss News*.

Flow and Flight Test Techniques

(See also Revs. 2479, 2544, 2596, 2612, 2623, 2637, 2645, 2653, 2654, 2657)

2671. **Kinderman, W. J., and Wales, E. W., Fluid flow through two orifices in series—The parameters of metastable and stable flow of hot water,** ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55-A-192, 11 pp. + 7 figs.

Authors attempt to explain the mechanism of flow through an orifice of water at a temperature higher than the saturation temperature corresponding to the downstream pressure. They produce a qualitative picture of the process in which the regimes of various types of flow are established quantitatively. The regimes include a metastable one in which the fluid remains liquid until it has passed the orifice, one in which steam bubbles form within the metastable liquid, and one in which the continuous phase within the orifice passage becomes vapor containing a dispersion of drops of liquid. Which regime obtains depends on the initial pressure, the initial temperature and, hence, vapor pressure and surface tension of the liquid, and the orifice configuration.

The behavior is observed by measurement of the pressure existing between two identical orifices in series. The dependence of this intermediate pressure on the flow regime suggests the adaptation of the experimental arrangement to a commercial firm of "steamtrap."

A. M. Mayers, USA

2672. **Head, V. P., A practical pulsation threshold for flowmeters,** ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55-A-188, 13 pp. + 2 figs.

2673. **Wehrmann, O., and Wille, R., Hot-wire anemometer for measurements in unsteady flow,** *AF tech. Rep.* AFOSR-TN-56-26, 18 pp. + 18 illus., 1955.

Technique described is an attractive solution to the hot-wire anemometry problem. The hot-wire bridge is excited by a 50-kcps power oscillator controlled by the amplified and rectified bridge output to give constant wire temperature. Wire temperature is controlled by initial amplifier gain setting (or bridge unbalance).

After demodulation, the output signal is "logarithmatized" electronically, operated on by the King fourth-power exponent by gain alteration, and then "delogarithmatized." The output is amplified and fed to an oscilloscope for recording. Detail circuitry is given without values.

Suitability of the apparatus is shown in its application in measuring fluctuating velocities in the scavenging ports of a two-stroke engine model. A 15μ diam wire 5 mm long on rigid supports was used. Velocity changes of the order claimed, viz. 0–100 m/s within one-fifth second, are shown in oscillograms; there is a brief discussion of their implications.

The carrier system avoids the use of dc amplification with low level input, but reviewer believes the "functional" circuitry (essentially dc amplifiers depending on tube characteristics) may need careful checking in continued use.

R. Culver, Australia

2674. **Voice, E. W., Bell, E. B., and Gledhill, P. K., Radioactive determination of gas flow in large ducts,** *J. Iron Steel Inst. Lond.* **177,** part 4, 423–427, Aug. 1954.

It is sometimes desirable to know the gas flow in large ducts or chambers when operating at high temperatures and under high or reduced pressures. Usual methods, such as pitot-tube surveys, may not be convenient owing to the geometry and conditions of the installation. A radioactive tracer method is described which is applicable, provided that two positions can be chosen such that adequate mixing occurs between them.

A pulse method is used, which gives, in addition, information on the transit time through the system, indicating whether there is appreciable recirculation or a clean sweep-through.

From authors' summary

2675. **Barry, F. W., Determination of Mach number from pressure measurements,** *Trans. ASME* **78,** 3, 581–589, Apr. 1956.

Discussion of the errors introduced by using various combinations of measured pressures to compute Mach number, especially in supersonic flow. Pressures measured with total, static, conical, and two-dimensional wedge probes are considered. Procedure is developed for estimating the effect on computed Mach number of errors in the measured pressures, or in the assumed values of the ratio of specific heats and of probe-deflection angle. Results of the error analysis for 10 pressure-ratio combinations from total, static, and wedge probes are presented analytically and in graphical form. In general, a Mach number computed from a pressure ratio involving the isentropic stagnation pressure is least sensitive to errors, and one computed from the ratio of static pressure on the wedge surface to free-stream static pressure is most sensitive. A brief review of some other considerations in choosing pressure instrumentation is included.

From author's summary by W. C. Griffith, USA

2676. **Marschner, B. W., The flow over a body in a choked wind tunnel and in a sonic free jet,** *J. aero. Sci.* **23,** 4, 368–376, Apr. 1956.

Pressure distribution over a double wedge airfoil under free flight conditions with Mach number 1 is compared with the pressure distribution over the same airfoil in a choked closed wind tunnel and in a sonic free jet.

Computation is carried out as a development with respect to a parameter which indicates the deviation from free flight conditions at Mach number 1.

Results illustrate the question of wind-tunnel corrections; deviation from free flight at Mach one have about the same magnitude for free jet and choked tunnel, but opposite sign, and are unexpectedly small. Thus, transonic testing in a closed tunnel near choking may not be as inaccurate as is usually assumed.

From author's summary by G. Guderley, USA

2677. Dixmier, G., Manufacturing airplane models of plastics (in French), *ONERA NT* no. 33, 61 pp., 1956.

The use of plastic materials reinforced by glass cloth permits the construction of models which satisfy the diverse requirements of various aerodynamic tests. Model can be constructed as a hollow shell, solid, as a shell filled with plastic foam, or with metal frame works, or other devices embedded or enclosed in the plastic. The method consists of making a rigid skin by dressing a female mold with glass cloth impregnated with resin.

Paper describes the methods of construction of models for hydrodynamics, wind-tunnel, and flight test in which the requirements vary as to smoothness, weight, stiffness, accuracy, and stability. It would be a useful summary for many groups considering such construction techniques.
P. Donely, USA

2678. Mathews, C. W., Theoretical study of the tunnel-boundary lift interference due to slotted walls in the presence of the trailing-vortex system of a lifting model, *NACA Rep.* 1221, 19 pp., 1955.

Equations give interference on trailing-vortex system of uniformly loaded finite-span wing in circular tunnel with partly open walls. Methods are given for treating tunnel shapes other than circular, a rectangular shape being considered as an example, and for dealing with nonuniform wing loading.

If there are four or more slots, it is found that the slot area required to give zero interference is small. The ratio of the slotted-tunnel interference to the closed-tunnel interference at the center of the model is approximately independent of model span. Tunnels with an odd number of slots or nonsymmetrical slot arrangements cause an additional rolling moment or a cross flow on the wings, or both.

According to subsonic linearized flow theory the results are not affected by compressibility.
From author's summary by D. W. Holder, England

2679. Chen, Y.-N., Unsteady boundary conditions for a transition zone caused by cross-section change in a one-dimensional unsteady flow of gas (in German), *ZAMP* **6,** 4, 274–296, 1955.

Equations for one-dimensional unsteady flow in a channel of varying area are applied to transient waves using method of characteristics. Author points out that such problems are often treated from steady flow solutions and that results may be quite misleading in certain cases. Examples of specific flows are given; among the most interesting may be applications to shock-tube flow. Advantages in using a tube of varying area have been partially obscured in the past by a lack of theoretical solutions. See, however, AMR **6,** Rev. 2038, and **8,** Rev. 593 for earlier consideration of the problem.
W. C. Griffith, USA

2680. Humphreys, M. D., An investigation of a lifting 10-percent-thick symmetrical double-wedge airfoil at Mach numbers up to 1, *NACA TN* 3306, 35 pp., Nov. 1954.

Subsonic and transonic pressure-distribution and drag-coefficient measurements on a two-dimensional 10%-thick symmetrical double-wedge airfoil for a range of angles of attack are presented and compared with theory and existing experimental data.
From author's summary

2681. Crooks, P. V., and Howard, W., Low speed tests on three aerofoil cascades designed for prescribed surface velocity distributions, *Aero. Res. Labs., Melbourne, Austral. Rep.* ME. 76, 16 pp. + 19 figs., June 1954.

The performance of three new blade shapes designed by the exact Lighthill method to have prescribed velocity distributions has been measured and compared with that of a conventional compressor airfoil in cascade.

One of these airfoils has been shown to have a lower drag over the whole working range and a wider range of operation.

Using a boundary-layer visualization technique, it has been shown that on these low-speed tests the performance of all the airfoils is limited by laminar separation. This limitation can be expected to apply in at least the first stages of any axial compressor and is, therefore, considered to be a problem of major importance.

The tests were performed at chord Reynolds numbers near 2×10^5.
From authors' summary

2682. Queijo, M. J., Jaquet, B. M., and Wolhart, W. D., Wind-tunnel investigation at low speed of the effects of chordwise wing fences and horizontal-tail position on the static longitudinal stability characteristics of an airplane model with a 35° sweptback wing, *NACA Rep.* 1203, 29 pp., 1954.

Low-speed tests of a model with a wing swept back 35° at the 0.33-chord line and a horizontal tail located well above the extended wing-chord plane indicated static longitudinal instability at moderate angles of attack for all configurations tested. The present investigation was made to determine whether the longitudinal stability could be improved by use of chordwise fences, by lowering the horizontal tail, or by a combination of both.
From authors' summary

2683. Godderum, P. B., and Wood, G. P., Experimental investigation of the flow around lifting symmetrical double-wedge airfoils at Mach numbers of 1.30 and 1.41, *NACA TN* 3626, 86 pp., Mar. 1956.

Measurements were made of the flow around a 10%-thick, doubly symmetrical, two-dimensional wedge at a Mach number of 1.30 and a 14.2%-thick wedge of Mach numbers of 1.30 and 1.41 for various angles of attack up to 5°. Pressure and Mach number distributions, lift and drag coefficients, center of lift, and pitching moment are presented for the angles of attack used. By means of the transonic similarity laws, the results are compared with each other, with small-disturbance theory, and with shock-expansion theory wherever possible. The data show that pressure distributions on wedges of different thickness and Mach number are similar at the same values of transonic similarity parameter and reduced angle of attack for angles of attack as large as the thickness ratio and that the lift-curve slope and chordwise position of the center of pressure are only roughly independent of angle of attack for the range of angles investigated.
From authors' summary

2684. Lord, W. T., and Beastall, D.; Lord, W. T., Hunt, G. K., Pallant, R. J., and Turner, J., Calibration of the R.A.E. no. 18 (9 in. × 9 in.) supersonic wind tunnel. Part I. Preliminary investigations; Part II. Tests at atmospheric stagnation pressure, *Aero. Res. Counc. Lond. curr.* Pap. nos. 162, 163; 44 pp., 24 pp., 1954.

A detailed account is given of the investigations performed in the variable density supersonic wind-tunnel prior to an extensive calibration of the tunnel. The variables which have an important effect on the behavior of the flow are described. The results of the investigations serve to define the course of the complete calibration, and may provide a useful guide to future calibrations of similar supersonic tunnels. The calibration program is outlined. Part II deals with tests at atmospheric stagnation pressure, and further tests at various stagnation pressures are proposed.
From authors' summary

2685. Taylor, J., Design and use of counting accelerometers, *Aero. Res. Counc. Lond. Rep. Mem.* no. 2812, 11 pp., 1954.

The fundamental principles underlying acceleration recording by means of a counting accelerometer are analyzed. The essential design requirements for a counting accelerometer are presented. A design that has been specially made to meet these requirements is described. Both mechanical and electrical counting are considered, but mechanical counting is found to be superior.
From author's summary

Thermodynamics

(See also Revs. 2432, 2436, 2547, 2548, 2569, 2575, 2610, 2664, 2665, 2699, 2706, 2716, 3717, 2718, 2724, 2729, 2730, 2738, 2741, 2747, 2755)

2686. Smith, J. M., and Bennett, C. O., Thermodynamics, *Indust. Engng. Chem.* **48,** 3 (part 2), 676–684, Mar. 1956.

Fourth annual review of fundamentals of chemical engineering.

2687. Prigogine, I., and Mayer, G., Fluctuations in stationary systems not in equilibrium, *Acad. roy. Belgique, Bull. Cl. Sci.* (5) **41,** 1, 22–29, 1955.

In the treatment of fluctuation phenomena in nonequilibrium systems it has been previously assumed without proof that the classical fluctuation theory for systems in thermodynamic equilibrium is valid. In this

paper, authors show that the production of entropy due to fluctuations is that of an equilibrium system in which the generalized forces are equal to the perturbation values. They then demonstrate that the classical Einstein formula for the probability of a fluctuation can be applied to nonequilibrium systems under conditions where the theorem of minimum entropy production holds (linear relations between fluxes and generalized forces; Onsager reciprocity relations). Two examples, one concerning temperature fluctuations in thermal conduction, and the other fluctuations of the Knudsen thermomolecular pressure, are considered in detail. L. M. Grossman, USA

2688. Boersma, S. L., A theory of differential thermal analysis and new methods of measurement and interpretation, *J. Amer. ceram. Soc.* **38,** 8, 281–284, Aug. 1955.

A theory of differential thermal analysis is developed relating temperature-peak area to the dimensions and thermal properties of the sample and the sample holder in the existing experimental arrangement. The influence of heat conduction through the thermocouple leads is shown to reduce the peak area by a factor of the order two. Short-comings of the method are discussed on the basis of this theory.

It is shown how these shortcomings can be overcome by using a different technique in which the peak area depends only on the total heat of reaction produced and not on other properties of the sample. In this technique the sample and the inert material are placed in identical small nickel containers which can exchange heat with a larger nickel body through a ceramic plate. The difference in temperature between the two small containers is measured by means of a thermocouple. It is stated that experiments with samples of $CuSO_4$ have quantitatively confirmed these views.

A simple electrical apparatus is suggested to synthesize a complex temperature curve as a linear combination of curves produced by known pure minerals. D. A. de Vries, Australia

2689. Greenspan, M., Simple derivation of the Boltzmann-Ehrenfest adiabatic principle, *J. acoust. Soc. Amer.* **27,** 1, 34–35, Jan. 1955.

The time-average forces exerted by the constraints of a vibrating system (radiation pressure, mean tension in a vibrating string, etc.) are easily computed from the adiabatic principle of Boltzmann and Ehrenfest. The usual derivation from the "principle of varying action" is difficult.

Here an equivalent principle (which gives, in addition, the time dependence of the forces) is derived from Lagrange's equations. It is also shown how similar results can be had from the solution of a linear differential equation with slightly variable coefficients.

From author's summary

2690. Rant, Z., Exergie, a new word for availability (in German), *Forsch. Geb. Ing.-Wes.* **22,** 1, 36–37, 1956.

The quantity which Guoy first introduced and called "énergie utilisable" [*C. R. Acad. Sci. Paris*, Mar. 11, 1889] has been variously rediscovered and named "technical free energy" (Stodola), "technische Arbeitsfähigkeit" (Bosnjakovic) (mainly in German literature) and "availability" (Keenan), etc.

Since its first introduction and up to most recent dates, a number of papers have appeared discussing its significance, the best one in reviewer's opinion being that by Keenan, [*Brit. J. appl. Phys.* **2,** 183–192, 1951; AMR **5,** Rev. 892]. For this quantity, author proposes the name "exergy" coined from the Greek syllables "ex" (out) and "erg" (work).

L. S. Dzung, Switzerland

2691. Woolley, H. W., Thermodynamic properties of gaseous nitrogen, *NACA TN* 3271, 144 pp., Mar. 1956.

The NBS-NACA tables of thermal properties of gaseous nitrogen are grouped together in this report for convenient use. They include the thermodynamic functions for the gas, both real and ideal, the transport properties for the gas, and the vapor pressure of the liquid and the solid. The tables are in dimensionless form, and conversion factors to frequently used units are given. Deviation plots or tables indicating the agreement or discordance of the experimental data are included.

From author's summary

2692. Vereshchagin, L. F., and Kalashnikov, Ya. A., Production of high temperatures at high pressures (in Russian), *Zh. tekh. Fiz.* **25,** 8, 1508–1517, Aug. 1955.

Book—2693. Daniels, F., and Duffie, J. A., editors, Solar energy research, Madison, Wis., University of Wisconsin Press, 1955, xv + 290 pp. $4.00.

Book presents thirty-seven articles by authorities in the field of solar energy. Topics are well chosen and organized to represent most of the areas of primary interest, from world energy demands and the general nature of solar energy through space heating, solar power plants, and water evaporation to suggestions for future research. Other chapters treat fundamental subjects such as photosynthesis, photochemistry, research with solar furnaces, and conversion of solar energy to electricity. Although later publications offer more recent data and more extensive bibliographies, this book must be included in any thorough review of the subject. P. Erlandson, USA

Heat and Mass Transfer

(See also Revs. 2435, 2463, 2471, 2472, 2575, 2583, 2604, 2605, 2624, 2626, 2687, 2688, 2689, 2690, 2692, 2693, 2753, 2783, 2788, 2789)

2694. Eckert, E. R. C., Hartnett, J. P., Isbin, H. S., and Schneider, P. J., Heat transfer, *Indust. Engng. Chem.* **48,** 3 (part 2), 655–668, Mar. 1956.

Fourth annual review of fundamentals of chemical engineering.

2695. Bertschinger, H., Heat-transfer problems of civil engineering, and numerical evaluation of forms and examples for symmetrical cases (in German), *Schweiz. Arch.* **21,** 9, 273–289, Sept. 1955; **21,** 11, 361–375, Nov. 1955; **22,** 2, 50–62, Feb. 1956.

Paper is an attempt at developing practical methods for solving problems of heat flow in solid bodies which civil engineers meet with in carrying out construction works of hydraulic power plants. Approximate methods are based on solutions of temperature distributions and heat-flows obtained by means of classical mathematical methods in slabs, hollow cylinders, and spheres, which have one boundary surface completely insulated and one through which heat can transfer.

First part of paper deals, therefore, with differential equations and their solutions for mentioned special forms of bodies. Second part presents graphs for eigenvalues of solutions given in first part and numerical examples for symmetrical cases; i.e., the determination of temperature distribution in a concrete wall 9-m thick exposed to natural temperature of surroundings, which contains following computations: (a) Heat exchange between wall and surroundings and mean wall temperature; (b) temperature and heat flux inside the body; (c) temperature of the surface which is completely insulated against surroundings and temperature in ½ and ⅔ of the thickness of the wall. Third part of paper is a continuation of the preceding part and contains a numerical example of influence of artificial cooling of a concrete mass by means of inserted cooling tubes through which brook water of variable temperature and intensity flows.

Paper will be continued. It is written in a telegraphic style and, without a tedious study, reader can hardly make out where classical mathematical methods end and in what the approximation of the whole solution consists. Reviewer believes that, for a civil engineer equipped with current mathematical knowledge but who is not well acquainted with mathematical theory of heat conduction, the article will not be comprehensible. F. Krupka, Czechoslovakia

2696. Goldenberg, H., Some numerical evaluations of heat flow in the region bounded internally by a circular cylinder. *Proc. phys. Soc. Lond.* (*B*) **69,** 434, 256–260 (Research Note), Feb. 1956.

Solutions to the transient heat-flow equation in the region exterior to a circular cylinder of radius a are given graphically. Initial temperature is zero; cylinder boundary temperature is constant.

Temperatures at radial distances $2a$, $10a$, and $100a$ are shown for the time range from $(a^2/D)10^{-1}$ to $(a^2/D)10^{5}$ where D is the thermal diffusivity. Integrated heat flux at the cylinder wall is given over the same range. These results are an extension of those given in Carlslaw & Jaeger, "Conduction of heat in solids," Oxford Univ. Press, 1947, pp. 280-3.

J. Lorell, USA

2697. Dyban, E. P., Kondak, N. M., and Shvets, I. T., Investigation of contact heat exchange between machine parts (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 9, 63–79, Sept. 1954.

Report on experimental research of parameters affecting the heat flow between metal parts with particular reference to power buckets in turbomachines. Temperature differential, surface finish, degree of contact pressure, different metals, surface hardness (gross and micro), oxidized coating, plating of surface with soft metals, and the nature of ambient gases were considered systematically for their over-all and reciprocal effect on heat-conduction coefficients.

Tests were run by setting up a stack of two metal blocks with calibrated thermocouples inserted at regular intervals down the height; applying measured electrical heat at the upper end; measuring calorimetrically the heat dissipated at the lower end, and surveying the temperature distribution along the height and across the parting line. Results are clearly presented and experimental accuracy well documented, but researchers declare that their aim for simpler analytical relationships could not be achieved, particularly because of the utter randomness of the areas of direct metallic contact as opposed to the air gaps always present between surface microasperities.

The empirical approach is therefore recommended.

B. Posniak, USA

2698. Pipes, L. A., Matrix analysis of heat transfer problems, Heat Transfer Fluid Mech. Inst., Univ. Calif., 187–197, 1954.

Author illustrates the solution of typical heat-conduction problems in steady, transient, and periodic flow by the use of operational methods and matrix algebra. The Laplace-transform method is particularly powerful for the treatment of composite structures, and a matrix formulation is shown to further economize on the effort in obtaining such solutions. P. J. Schneider, USA

2699. Filippov, L. P., and Novoselova, N. S., Heat conductivity of normal liquid solutions (in Russian), *Vestnik Moskov. Univ. Ser. Fiz.-Mat. Estest. Nauk* (2) **10,** 3, 37–40, Mar. 1955.

Article covers heat conductivity investigations of the following normal organic solutions: (1) Benzene, chloroform, and carbon tetrachloride at 15 C; (2) toluene and carbon tetrachloride at 15 C and 30 C; (3) chloroform and benzene at 15 C; (4) chloroform and phenylchloride at 30 C; (5) benzene and carbon tetrachloride at 15 C; (6) chloroform and ether at 15 C.

Heat-conductivity measurements were carried out with temperature differences of 4 C and 2 C by methods of cylindrical films. Method is not described and referred to work of others.

Of the seven cases investigated, given in order outlined above, plotted on graphs, six show that in each case the heat-conductivity curve of the solution lies between those of their components. The graphs are presented by parabolic concave curves bent upward.

The seventh conductivity graph, chloroform-ether solution, showing superimposed curves of the components, must be rejected because of heat release while preparing the solution. W. Green, USA

2700. Bibikov, D. N., Heat transfer from bottom to nonfreezing stream (in Russian), *Gidrotekh. Stroit.* **22,** 10, 32–34, 1953.

Paper considers the problem of rate of heat flow from river bed to water in the absence of ice at top. Only heat conduction in one dimension is considered and the problem is treated in conventional manner with the aid of the Fourier equation (with time dependence included).

The boundary conditions of the application do not correspond with the known solution applied (heat conduction in slab), and author devotes some time to selecting a reasonable instant of time starting from which the solutions might be used for the problem in hand.

J. Kestin, USA

2701. Talbot, A., and Kitchener, J. A., Diffusion (or conduction) along a slightly tapering tube, and its application to the determination of diffusion coefficients, *Brit. J. appl. Phys.* **7,** 3, 96–97, Mar. 1956.

The diffusion equation has been solved for the case of diffusion from a slightly tapering tube into an infinite medium of zero concentration. The theory provides a means of correcting results obtained for diffusion coefficients in the capillary tube method of Anderson and Saddington, when the tube is not of uniform bore throughout its length. This is frequently the case when silica capillary tubes have to be used (as for high-melting substances), and the correction is often significant. From authors' summary

2702. Persson, P. O., Insulation investigations (in Swedish), *Kyltekn. Tidskr.* **13,** 5, 73–76, Oct. 1954.

Heat flow meters must be used in many cases to investigate the efficiency of heat insulation in finished plants. Two types of heat flow meters were designed and constructed at the Royal Institute of Technology, Stockholm, Sweden. One of them was utilized to measure widely varying rates of flow. It is provided with a U-shaped glass tube, which is evacuated and partly filled with liquid. One leg is placed in that part of the meter which is in contact with the wall, and therefore has the same temperature as the wall surface. The other leg is fitted in that part of the meter which faces the room. The temperature of this leg is slightly closer to room temperature. The liquid in the warmer leg evaporates, and is condensed in the colder leg. The quantity of liquid transferred is a measure of the product of heat flow and time. The other type is a small meter designed to measure more or less stable heat flow and to determine heat flow distribution on wall surfaces. These meters are equipped with built-in thermocouples and are so thin that their inertia is extremely low. They were used for several purposes; e.g. to demonstrate that the interior air current in a wall insulated with corrugated foil can destroy the insulating capacity of the wall, and that large quantities of heat can be transferred by water vapor in glass-wool-insulated ceilings of cold-storage rooms from upper to lower insulation layers. G. Brown, Sweden

2703. Ekelöf, S., Temperature distribution in a long metal cylinder of circular section carrying direct electric current (in German), *Trans. Chalmers Univ. Technol.* no. 167, 38 pp., 1955.

Paper deals with time-dependent and steady-state radial distributions with Newtonian surface cooling. Problem is of interest in metal hardening by resistance heating and in setting of concrete. Specific heat, thermal conductivity, and density are assumed constant throughout. Author recapitulates known solution for constant specific resistance ρ and Newtonian coefficient h and derives simple approximations when Nusselt number is small. To take account of temperature variation of ρ, h, he replaces space derivatives by finite differences and derives approximate expressions for temperature difference between axis and surface, using a single radial interval. Several numerical examples are worked out on a Bush-type analyzer. Appendix briefly describes this machine, which has 6-mm diam vertical shafts, small light gears, and integrators employing two output wheels operating a differential. No torque amplifier is needed, and addition of a frontlash mechanism (not described) achieves over-all error of $< \frac{1}{4}\%$ even in oscillatory solutions. S. Paterson, Scotland

2704. Dul'nev, G. N., and Kondrat'ev, G. M., A universal relation between the thermal inertia of a body and the influence to which it is subjected by its surroundings (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 3, 130–138, Mar. 1955.

In studying the heat exchange between a solid body and the surrounding materials, two assumptions are made: (a) The temperature difference is assumed to diminish according to an exponential function of the time; (b) a linear combination of the temperature difference and its internal normal gradient is supposed to vanish identically. The solution of this problem depends accordingly upon two numerical parameters, i.e., the constant in the exponent (thermal inertia) and the constant in the boundary condition which is related to the heat-transfer coefficient. A relation between these parameters is established and evaluated for solids of simple shape. This relation turns out to be fairly insensitive to changes in the shape of the body; the authors speak accordingly of a universal relation. Although the universal character of the result obtained is not well substantiated, the numerical and graphical results obtained in this paper may be useful for further computations. R. Eisenschitz, England

2705. Diffusion coefficients in hydrocarbon systems. *Indust. Engng. Chem.* **48,** 2, Feb. 1956: **Reamer, H. H., Opfell, J. B., and Sage, B. H., Methane-decane-methane in liquid phase,** 275–282; **Reamer, H. H., Duffy, C. H., and Sage, B. H., Methane-n-pentane-methane in liquid**

phase, 282–284; **Reamer, H. H., Duffy, C. H., and Sage, B. H., Methane-white oil-methane in liquid phase,** 285–288.

This series of papers represents another important contribution to the literature by Prof. Sage and his coworkers at the California Institute of Technology. Consideration is herein given to the evaluation of a Fick diffusion coefficient under conditions such that the effect of the change in volume of the liquid phase cannot be neglected. Transport equations are derived which describe the diffusional model proposed and experimental data presented covering a very wide range of temperature and pressure operation. Based upon the assumption of negligible resistance to mass transfer at the two-phase interface, the results show that the diffusion coefficient is a function of the liquid composition. Changes of the order of magnitude of 300% are indicated as possible.

L. Lapidus, USA

2706. Saxena, S. C., Higher approximations to diffusion coefficients and determination of force constants, *Indian J. Phys.* **29,** 10, 453–460, Oct. 1955.

Author shows that going to the third approximation for computation of coefficients of self-, inter-, and thermal diffusion according to scheme of Chapman and Cowling does not appreciably modify results of second approximation. He concludes that method of Srivastava and Madan [*Phil. Mag.* **43,** p. 968, 1952; *Proc. phys. Soc. Lond.* (A) **66,** p. 277, 1953 (AMR **7,** Rev. 295)] is therefore valid.

I. M. Krieger, USA

2707. Liebmann, G., A new electrical analog method for the solution of transient heat-conduction problems, *Trans. ASME* **78,** 3, 655–665, Apr. 1956.

Solution of transient problems by electric analogy was carried out by using lumped spatial parameters but continuous time parameter, using resistance-capacitance network. By using a more complex pure resistance network, author solves such problems with finite steps both spatially and in time. Method involves an iteration procedure, of the same kind as used in finite difference method. Problems with constant and varying parameters, one- or two-dimensional in spatial arrangement, can be handled. Advantages as opposed to *R-C* networks are lower cost and possibility to interrupt calculation at will; disadvantage, in reviewer's opinion, slower operation and, possibly, less versatility.

V. Paschkis, USA

2708. Wiegand, J. H., Simplified unsteady-state conduction calculations, *Indust. Engng. Chem.* **48,** 4, 817–820, Apr. 1956.

Author presents graphical results for the temperature history in infinite plates, infinitely long solid cylinders, and solid spheres during heating or cooling from an initial uniform temperature to a uniform ambient temperature and with a uniform surface resistance.

These results are based on only the first term in the series solutions, and hence are restricted to the later period of heating or cooling. Unfortunately many of the critical problems of current interest are concerned with relatively short heating periods for which many terms of the series solutions are required.

P. J. Schneider, USA

2709. Douglas, J., Jr., Peaceman, D. W., and Rachford, H. H., Jr., Calculation of unsteady-state gas flow within a square drainage area, *J. Petr. Technol.* **7,** 11, 190–195, Nov. 1955.

The problem of unsteady-state gas flow through porous media has been solved numerically only for the case of linear or radially symmetric reservoirs. A recently introduced numerical method for solving the unsteady-state heat flow equation in two dimensions is applied to the calculation of the depletion of a square region containing a perfect gas. Solutions are presented in graphical form for various values of dimensionless parameters. The solutions are compared with published solutions for radial reservoirs.

From authors' summary by J. S. Aronofsky, USA

2710. Dorrance, W. H., The effect of mass transfer on the compressible turbulent boundary-layer skin friction and heat transfer—an addendum, *J. aero. Sci.* **23,** 3, 283–284 (Readers' Forum), Mar. 1956.

A constant of integration in a previous paper of the same author [*J. aero. Sci.* **21,** 6, 404–410, 1954; AMR **8,** Rev. 734] is adjusted so that better agreement is obtained with measurements published since the author's first paper appeared.

H. Schuh, Sweden

2711. Bondnarescu, M. V., Contribution to the theory of heat transmission in laminar flow (in German), *VDI-Forschungsheft* **21,** 450, 19–27, 1955.

The problem of heat transfer to a fluid flowing in a circular pipe of radius a with a Poiseuille velocity distribution depends on the equation

$$(\partial^2\theta/\partial r^2) + (1/r)\,(\partial\theta/\partial r) + (\partial^2\theta/\partial x^2) = (2u_m/\kappa)\,[1 - (r/a)^2]\,(\partial\theta/\partial x)$$

where θ is the temperature of the fluid, r measures distance from the axis, and x is distance downstream. The value of θ has been found by Graetz and Nusselt ["Modern developments in fluid dynamics; high speed flow," p. 774; Oxford 1953] when there is a discontinuous rise in temperature at the boundary, on the assumption that $\partial^2\theta/\partial x^2$ may be neglected. Author uses the method to solve more general problems both for flow in a circular pipe and for flow between parallel plane walls. In the latter case, he also solves Graetz' problem without neglecting $\partial^2\theta/\partial x^2$. This is done by using a Fourier transform, whereas previously a series of eigenfunctions, which were only orthogonal if $\partial^2\theta/\partial x^2$ is negligible, was used. It appears from the table he gives that the values of the Nusselt numbers neglecting $\partial^2\theta/\partial x^2$ are in excess by varying amounts up to 8%.

K. Stewartson, England

2712. Hall, W. B., and Crofts, T. I. M., Use of sodium and of sodium-potassium alloy as a heat-transfer medium. Parts I, II, *Engineer, Lond.* **201,** 5217, 5218; 102–104, 128–130, Jan. 1956.

2713. Brun, E., Brunello, G., and Vernotte, M., Measurement of heat-transfer coefficients on cylinders with forced convection and with rough surface (in French), *C. R. Acad. Sci. Paris* **242,** 2, 227–229, Jan. 1956.

2714. Eckert, E. R. G., Engineering relations for heat transfer and friction in high-velocity laminar and turbulent boundary-layer flow over surfaces with constant pressure and temperature, ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap.55-A-31, 11 pp.

Relationships developed adapt the equations for skin friction and heat transfer in low-speed, constant-property fluids to high-speed flow wherein properties vary. Method employs low-speed equations with all fluid properties evaluated at a certain reference temperature. Because reference temperature is simply expressed explicitly as a function of Mach number and wall-to-stream temperature ratio, the method developed is very easy to apply. Calculated results agree remarkably well with known exact solutions to laminar boundary-layer equations and with experimental data for turbulent boundary layers. For some applications, a reference enthalpy rather than a reference temperature is employed.

D. R. Chapman, USA

2715. Hartnett, J. P., and Eckert, E. R. G., Mass transfer cooling in a laminar boundary layer with constant fluid properties, ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55-A-108, 16 pp. + 15 figs.

Heat-transfer coefficient, mass-transfer coefficient, skin friction, and recovery factor are given for flat plate and stagnation flow with suction or injection velocities inversely proportional to the square root of the distance from leading edge. Under these conditions the relevant data can be taken from the so-called similar solutions of the boundary-layer equations. The injected gas is assumed different from that of the main flow, so that both heat transfer and diffusion take place simultaneously. Compressible flow with constant property values is considered for flat-plate flow. Results are applied to three kinds of cooling: by mass transfer with a gas or liquid, and by sublimation. Authors present earlier published material supplemented by new calculations.

H. Schuh, Sweden

2716. Wilke, C. R., and Prausnitz, J. M., Mass transfer, *Indust. Engng. Chem.* **48,** 3 (part 2), 669–675, Mar. 1956.

Fourth annual review of fundamentals of chemical engineering.

2717. Acrivos, A., Method of characteristics technique. Application to heat and mass transfer problems, *Indust. Engng. Chem.* **48,** 4, 703–710, Apr. 1956.

While the method of characteristics has been used in the fluid dynamic field for a number of years, this represents the first application to chemical engineering. Consideration is given to developing the basic techniques of this numerical method and a number of applications are considered. These include problems in mass and heat transfer, with

chemical reaction, in packed beds. In each case the problem is discussed in great detail. A numerical example describing the transient behavior of a drying packed column is also described and compared with literature data. L. Lapidus, USA

2718. Alexander, K. F., On recent theories of thermal diffusion in liquids, *Physica* **21,** 5, 446–448 (Letter to the editor), May 1955.

The relation between the single heat of transfer for binary systems obtained from thermodynamical theory and the two independent heats of transfer obtained from kinetic theory is discussed.

H. D. Block, USA

2719. Sparrow, E. M., and Gregg, J. L., Laminar free convection from a vertical plate with uniform surface heat flux, *Trans. ASME* **78,** 2, 435–440, Feb. 1956.

Authors solve numerically the free-convective laminar boundary-layer equations for a vertical flat plate with uniform surface heat flux, at Prandtl numbers of 0.1, 1, 10, and 100. The local surface temperature difference from ambient is correlated graphically with a local Nusselt-Grashof number product $(g\beta x^4 q/\nu^2 k)$ for Prandtl numbers between 0.01 and 100.

The results are of use in approximating operating temperatures in designing equipment with constant heat-generation permit volume.

E. V. Somers, USA

2720. Levy, S., Integral methods in natural-convection flow, *J. appl. Mech.* **22,** 4, 515–522, Dec. 1955.

Paper extends integral method used in free convection to include bodies of arbitrary shape and large curvature. Nusselt numbers are computed for the specific cases of a vertical plate, a horizontal plate facing upward for laminar and for turbulent flow, an inclined plate with laminar and with turbulent flow, and a horizontal circular cylinder at constant temperature. Comparisons with more exact solutions or experiment (where available) yielded reasonable agreement.

Consideration is also given to flow in an enclosed rectangular channel. An outline of how Lighthill's method [AMR **7,** Rev. 2294] can be extended to include different wall thermal conditions is presented, but no solutions are given. Lack of clear definitions of several important quantities and the brevity of this section make it very difficult to comprehend.

Reviewer feels that the types of solutions to be expected should have been discussed. For example, it is not obvious from the paper that "eigenvalue-type" solutions similar to Lighthill's result from the analysis, although such is the case. S. Ostrach, USA

2721. Eckert, E. R. G., and Diaguila, A. J., Experimental investigation of free-convection heat transfer in vertical tube at large Grashof numbers, *NACA Rep.* 1211, 14 pp., 1955.

Local free-convection heat-transfer coefficients and temperature fields in the turbulent flow range were obtained within a vertical, stationary tube closed at the bottom, heated along its walls, and having a length-to-diameter ratio of 5. Convective heat-transfer coefficients were correlated by the general relations for free-convection heat transfer. These coefficients, converted to dimensionless Nusselt numbers, were 35% below known relations for vertical flat plates. Air temperature measurements within the tube indicated a thin boundary layer along the heated wall surface and unstable conditions in the air flow.

From authors' summary

2722. Berndorfer, H., Influence of air cooling system on the cooling conditions of air-cooled engine cylinders (in German), *Motortech. Z.* **15,** 10, 291–298, Oct. 1954.

Electrically heated cast-iron cylinders with four different guiding devices were experimentally investigated. Photographs of smoke patterns have been taken, and air consumption, pressure drop, and temperatures between cylinder ribs have been measured. Some characteristic data are plotted against the air flow and the relation between Nu and Re numbers is derived. It has been found that guiding device with broad entrance has given more even temperature distribution but a lower heat-transfer coefficient. The device of Messrs. Argus, and especially the design of the author, assure higher cooling effect by uniform temperature of cylinder surface. Inserted turbulent wires enable the reduction of air flow; the use of the suction principle involves greater power consumption but brings better air distribution in the case of motors with cylinders in line or in V.

O. Maštovský, Czechoslovakia

2723. Evans, F.-C., Radiating recuperator (in French), *Chaleur et Industrie* **37,** 368, 65–72, Mar. 1956.

2724. Godson, W. L., The computation of infrared transmission by atmospheric water vapor, Part II, *J. Meteor.* **12,** 6, 533–535, Dec. 1955.

Author shows that a newly proposed logarithmic ogive distribution function for line intensity of the infrared water-vapor spectrum gives better accuracy in calculating transmission and cooling rate than two previously proposed functions. [See also AMR **9,** Rev. 1261.]

A. Whillier, South Africa

2725. Ram, A., and Prasad, S. N., The transmission, absorption and reflection of solar radiations by glasses, *J. sci. indust. Res., India* **14A,** 12, 570–584, Dec. 1955.

Authors discuss the effect of coloring agents and other substances on the transmission properties of various types of glass. Solar radiation is not considered specifically, but transmission in the ultraviolet, visible, and infrared regions of the spectrum is given. Quantitative value of spectral transmission curves is marred by absence of glass thickness. Also, formulas quoted for calculating glass transmittance are approximations that are good only when the internal absorption of radiation in the glass is relatively small. Paper should be valuable guide to those interested in glasses with special transmission characteristics.

A. Whillier, South Africa

2726. de Grave, A., Method for calculating the mean temperature and the emission of heat from a heated ceiling (in French), *Ann. Trav. publics Belg.* no. 1, 49–58, 1955.

Author first examines analytically the problem of heat transfer from a section of a heated ceiling. The heat is supplied to the ceiling by heated tubes placed at finite spacings. Conduction, convection, and radiation effects are considered. Author, after solving for space mean temperature between rows of heating coils in the ceiling, solves a few numerical examples for the total heat transmission from the ceiling.

S. Eskinazi, USA

2727. Shorin, S. N., Radiant heat exchange in the cooling of gas turbine combustion chambers (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk,* no. 10, 99–111, 1954 (translated from Russian by M. D. Friedman, 572 California St., Newtonville, Mass., 19 pp.)

The part of radiant energy in power conversion in the flow of burning matter is analyzed theoretically. This development stems from the derivation of an energy equation similar to that obtained in the thermal theory of flame propagation, but also containing a radiant energy term.

Introduced is the concept of radiant temperature for the radiation field characteristics, which can be determined by an equivalent amount of radiant energy in a volume element of space under the conditions of thermodynamic equilibrium. By use of this concept, a formula is obtained which permits the determination of the heat transfer by diffuse radiation. I. Glassman, USA

2728. Smith, L. G., and Williamson, G. J., The development of a mechanical-draught water-cooling tower, *Proc. Instn. civ. Engrs.* **5,** 2 (part I), 86–117, Mar. 1956.

2729. Vits, H., Plotting the states of vapor-air mixtures for application in drying techniques (in German), *Forsch. Geb. Ing.-Wes.* **22,** 1, 9–20, 1956.

A t-v-p diagram is presented showing log t as a function of log y (air content of the mixture) with additional scales for vapor content and percentage, partial vapor pressure, specific heat of the mixture, and also lines of constant enthalpy, specific weight, φ (saturation), p/ϑ etc., in a wide range. Corrections are given to take into account the variation of properties within such large ranges. Most drying engineering problems may be solved adequately without considering these corrections. W. Gumz, Germany

2730. Krischer, O., and Esdorn, H., Heat transfer in wet porous media of various structure (in German), *Forsch. Geb. Ing.-Wes.* **22,** 1, 1–8, 1956.

The actual structure is replaced by a model consisting of four layers in parallel and four layers in succession. The four types represent conduction of heat in the solid, in the moisture, in air (dry pore walls assumed), and conduction and vapor diffusion in air with wetted pore walls. Measurements fit fairly well into the curves derived from such a model. W. Gumz, Germany

2731. Miller, F. G., and Seban, R. A., The conduction of heat incident to the flow of vaporizing fluids in porous media, *J. Petr. Technol.* 7, 12, 45–47, Dec. 1955.

Authors consider temperature and enthalpy changes occurring in a volatile liquid which flows slowly through a column of a porous material and which partially vaporizes in the column. An analysis is given for each of three flow regimes: a liquid flow region, a transition region, and a two-phase flow region. For the particular case of propane flowing through a sand column it is shown that (1) heat conduction can be neglected; (2) the change of temperature in the liquid flow region is small; (3) the transition region does not exceed a few pore diameters in thickness; and (4) the change of enthalpy in the two-phase flow region can be neglected. P. Chiarulli, USA

2732. Barbaro, D., Refrigeration of wet substances by vaporization in rarefied air currents (in Italian), *Termotecnica* **9,** 11, 534–540, Nov. 1955.

Author studies a modification of a known method for quick refrigeration of wet substances, in particular of vegetables [H. P. Hayes, "Vacuum cooling of produce," *Refrig. Engng.* Sept. 1954]. Instead of high vacuum, only 6 to 18 in. of mercury of absolute pressure are used, while evaporated humidity is removed by a current of air introduced with a De Laval tube. C. Codegone, Italy

2733. Berman, L. D., The role of liquid film resistance in some cases of evaporation and condensation in direct-contact heat exchangers containing gas-vapor mixtures (in Russian), *Zh. tekh. Fiz.* **24,** 6, 1022–1034, June 1954.

Author reviews critically the evaluation of experimental results obtained from direct-contact heat exchangers involving mass transfer at the liquid-gas interface. The discussion is restricted mainly to water-moist air cooling towers, and to moderate density heat fluxes (185–370 Btu/ft²h).

Objection is made to experimental procedures and evaluation of results given by McAdams, W. H., Pohlenz, J. B., St. John, R. C., *Chem. Eng. Progr.* **45,** p. 241, 1949; Mickley, H. S., *Chem. Eng. Progr.* 45, p. 739, 1949; Yoshida, F., Tanaka, T., *Ind. Engng. Chem.* **43,** p. 1467, 1951. Exception is taken in particular to the assumption that the resistance to heat flow within the liquid is comparable to the resistance in the gas vapor mixture. Author shows that this assumption is based on a circular argument and that it leads to contradictions in the interpretation of the results. Author quotes work [Virubov, D. N., *J. tech. Phys.* **9,** 1923; Prueger, W., *Z. Phys.* **115,** p. 202, 1940] which suggests that temperature gradients within the liquid are negligible, and that McAdams' experimental results can be interpreted in a different way. Y. R. Mayhew, England

2734. Jens, W. H., and Leppert, G., Recent developments in boiling research, *J. Amer. Soc. nav. Engrs.* **67,** 1, 137–155, Feb. 1955.

See also AMR **8,** Rev. 1820.

Book—2735. Kays, W. M., and London, A. L., Compact heat exchangers, Palo Alto, Cal. The National Press, 1955, xii + 156 pp. $5.

This book collects and correlates the work carried out by Professors Kay and London and co-workers, mainly for the American Office of Naval Research, between, and including, 1947 and 1954. The result is a comprehensive manual on the performance of compact heat exchangers and is an essential reference book for anyone involved in the design or use of heat exchangers. Basic heat-transfer and friction test data are presented for 88 surface configurations including (1) tube banks, with both circular and flattened tubes and both inside and outside flow; (2) plate-fin surfaces with a variety of fin types; (3) finned tube surfaces with both circular and flat tubes and various types of fins; and (4) screen and sphere matrix surfaces.

The presentation of this data is preceded by introductory chapters in which the design of heat exchangers is analyzed. The effect of temperature-dependent fluid properties, contraction and expansion pressure losses, etc., are considered, and comparisons are made between analytical and experimental data for flow in tubes.

The data are presented throughout in the form of nondimensional coefficients, mainly in terms of the Colburn factor, the friction factor, and Reynolds number. While this may be unpopular with some engineers, it is difficult to see how it could be avoided without making the book cumbersome in the extreme, and the presentation is such that the calculations involved to convert from the nondimensional groups to heat-transfer coefficients, pressure drops, velocities, and so on, should present no great difficulty.

The book is essentially a compilation of data, and no attempts are made to discuss the implication of the results or to compare the various types of heat-transfer surfaces used. While this does not detract from the present volume—in fact, any such discussion would be out of place—it is to be hoped that the authors will publish such an analysis in due course. It appears to the reviewer, from a quick study, that the pressure loss that has to be suffered for any rate of heat exchange is roughly similar in all the various types of surface and the selection of any design for a specific purpose should be governed by relating overall size with ease of manufacture, possibility of blockage, etc.
G. G. Thurlow, England

2736. Smirnov, M. M., On the integration of a system of differential equations (in Russian), *Prikl. Mat. Mekh.* **19,** 1, 127–128, 1955.

Author gives a closed-form solution of a system of two simultaneous differential equations encountered in heat transfer in cross flow by a method introduced by N. P. Yerugin [Uchen. Zap. Leningr. Gos. Univ. Math. Series 16, 1949]. These equations for the temperature distribution of the two steady streams flowing at right angles to each other are

$$\theta_x = C(T-\theta) \quad \text{and} \quad T_y = -a(T-\theta)$$

and the boundary conditions are

$$T(x, 0) = 1 \qquad \theta(0, y) = 0$$

These equations were first solved by W. Nusselt [*ZVDI* **55,** p. 48, 1911 and *Tech. Mech. u. Thermod.* **1,** 12, 1930], but the proposed solution is much simpler. Eliminating θ from the first equation and substituting in the second, and after some transformation, Yerugin's solution can be used. This yields for

$$T(x, y) = \exp(-ay - Cx)\ \{C\int_0^x \exp(Ct)\, J_0[2i(aby(x-t))^{1/2}]dt + J_0[2i(abxy)^{1/2}]\}$$

and

$$\theta(x, y) = -i\exp(-ay - Cx)\ \{C^2\int_0^x \exp(Ct)\, J_1[2i(aby(x-t))^{1/2}]\,(x-t)\,(aby(x-t))^{-1/2}dt + CxJ_1[2i(abxy)^{1/2}]\,(abxy)^{-1/2}\}$$

All quantities are nondimensional. M. Maletz, USA

2737. Dedusenko, Yu. M., Selection of heat engineering characteristics and reduction of the dimensions of tubular heat exchangers in gas turbines (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 8, 53–64, Aug. 1954.

Author states "Heat utilization of exhaust gases for preliminary heating of a working medium, as is known, is a very effective method to increase gas turbine efficiency. However, the application of a high regenerative cycle is restricted by an abrupt increase of both the thermal resistance as well as the size of the heat exchanger. Efforts to decrease the exchanger size are met with an increase in thermal resistance which in turn causes gas-turbine efficiency to decrease.

"To select optimum parameter of exchangers, it is necessary to establish their effect on the gas-turbine efficiency."

To do this, author, by a series of formulas, constructs a family of curves showing relation of the optimum degree of compression and maximum turbine efficiency for various heat-utilization values and overall pressure drop in the cycle.

The next step is an analysis of a counterflow heat exchanger with a

2000-hp installation having a 26% efficiency. In this analysis, by formulas and graphs, author shows that the heat release of outside tube surface is three times less than that of the inside tube surface.

The case of heat exchanger with cross-current flow shows an increase of exchanger volume, other conditions being equal, over that with counter-current flow.

Finally, the analysis of a finned tube counterflow exchanger shows it to be most economical; volume being ½ the size of an exchanger with smooth tubes.

Basic formulas as well as derived ones are of exclusive Russian sources; so is the bibliography. This seems odd to this reviewer, as the English language is quite rich in heat-transfer literature.

T. Green, USA

2738. Schack, A., Basic principles of heat recuperation (in French), *Chaleur et Industrie* **27,** 366, 11–15, Jan. 1956.

2739. Kotelewskij, G. P., Bubble contact heaters for power plants, *Indust. Engng. Chem.* **48,** 1, 20–25, Jan. 1956.

Average steam bubble velocity in water at 100 C was measured experimentally and found to be 2.25 fps at atmospheric pressure. Author extends calculations to design of bubble contact heaters, and adduces data to show that they would be progressively more economical than tube heaters, as operating pressure rises over 120 psi absolute. Author minimizes the effect of hammering at high operating pressures and suggests application to feed preheating in power plants.

A. R. Aikman, USA

2740. Ference, M., Jr., Stroud, W. G., Walsh, J. R., and Weisner, A. G., Measurement of temperatures at elevations of 30 to 80 kilometers by the rocket-grenade experiment, *J. Meteor.* **13,** 1, 5–12, Feb. 1956.

The temperatures in the region of the atmosphere between 30 and 80 kilometers have been determined from measurements of the velocity of sound in nearly vertical propagation. The sources of sound were grenades consecutively ejected from Aerobee rockets. The method of analysis of the data to obtain accurate temperatures is described, and the results are presented.

The temperature data are in good agreement with balloon data near 30 km and show a maximum of about 268K at 48 km. The probable errors are less than 3%. There are no clear-cut seasonal effects at the latitude of the firings, 32°N, although a number of marked irregularities in temperature in individual firings was noted.

From authors' summary

2741. Godridge, A. M., and Thurlow, G. G., The use of the suction pyrometer in pulverized-fuel-fired furnaces, *J. Inst. Fuel* **28,** 179, 601–609, Dec. 1955.

Paper describes difficulties met when using suction pyrometers to measure gas temperature in pulverized-fuel-fired furnaces in the range 1000–1400 C when the ash starts to become sticky and forms deposits on and in the pyrometer head. Description is given of a nichrome wire-gauze filter placed over the head and of how it extends the useful reading time of the pyrometer but simultaneously reduces its reading by about 60 C at 1100 C.

Paper further describes experiments on suction pyrometers with various refractory heads, showing that a robust refractory head with large-bore holes can be used satisfactorily at 1000–1500 C for a good hour before efficiency drops, and can easily be cleaned.

Authors discuss the effect on pyrometer's accuracy of material and thickness of refractory head, of number and size of holes, and of change of emissivity outside and inside the head due to deposits.

Reviewer sees in this work support for the refractory suction pyrometers established by the Wärmestelle, VDEh, Düsseldorf.

M. A. Saleh, Egypt

2742. Fokin, O. V., Natural thermocouple measurement of metal cutting temperature (in Russian), *Zh. tekh. Fiz.* **25,** 3, 436–446, Mar. 1955.

A set-up for measuring metal cutting temperature by the method of natural thermocouple consists of the following circuit: the cutting tool, the millivoltmeter, the object which is machined. The machined object is, of course, insulated from the bench. The tool and the object which is machined are made of different metals; thus an electric current is generated at the hot contact of the tool and the object. The current is measured by a voltmeter whose readings are translated into temperature. The contact area forms the hot end of a thermocouple.

The author of this paper made extensive investigations as to how reliable are readings from such a set-up. His theoretical analysis shows that the temperature is not constant throughout the contact area and that the readings could not show the maximum temperature. His experiments at the bench and on models simulating the actual set-up corroborated the theory fully. In the experiments was introduced an additional circuit connecting the tool with the nearest or the furthest point of contact, that is, the cold end of a thermocouple was at some point on the shaving itself. The results and the conclusions from his investigations are as follows: (a) the reading from the tool to the object circuit gives a temperature which is an average of the temperatures at the extreme ends of the contact area: (b) the maximum temperature is not proportional to that average; (c) readings from two circuits, the tool to the object (showing the average temperature) and the tool to the extreme end of the shaving circuit (showing the lowest temperature), permit a more accurate evaluation of the highest temperature on the working surface of the tool. A reliable value for the maximum temperature would help to establish better optimum conditions for metal cutting operations.

T. Leser, USA

Combustion

(See also Revs. 2668, 2705, 2727)

2743. Swarts, D. E., and Orchin, M., Vapor-phase oxidation and spontaneous ignition—correlation and effect of variables, *NACA TN* 3579, 32 pp., Apr. 1956.

The spontaneous ignition temperatures of eight structurally different hydrocarbons were determined and correlated with the behavior of the same hydrocarbons toward vapor-phase oxidation. Since good correlation of the two phenomena was obtained, it is likely that similar oxidative mechanisms are operative in both.

From authors' summary

2744. Mickelsen, W. R., and Ernstein, N. E., Propagation of a free flame in a turbulent gas stream, *NACA TN* 3456, 89 pp., July 1955.

Flame speeds of free flames in a turbulent propane-air stream were measured by photographic, ionization-gap, and photomultiplier tube methods. These measurements were made in both an enclosed tunnel and a free jet. The turbulent flame speeds measured by the authors for their free flames are less than those previously reported for flames stabilized on nozzle burners, Bunsen burners, and flame tubes. Flame speeds calculated from the turbulent-flame theories of Tucker [AMR 8, Rev. 2905] and Scurlock and Grover [AMR **7,** Rev. 4046] form the upper limits for the values measured for propagation rate of free flames.

A. C. Scurlock, USA

2745. Schultz-Grunow, F., Regularities of laminar flame propagation and their limits (in German), *Z. physikal. Chem. (N.s.)* **5,** 3/4, 204–231, 1955.

Paper discusses experimental data obtained by Jahn (1934) for the flame speed of chemical reactions in various mixtures of gases (H_2, O_2, N_2; H_2, O_2, CO_2; CO, O_2, N_2; CO, O_2, CO; CH_4, O_2, N_2; CH_4, O_2, CO_2). A number of dimensionless parameters referring to each reaction are calculated, following ideas presented by the author in a previous paper [AMR **7,** Rev. 611]. Data concerning the coefficients of diffusion and of heat conduction necessary for the calculations are presented in diagrams. The results are collected in another set of diagrams, representing the dependence of a dimensionless reaction speed on certain other parameters. Author points out that the results obtained make it possible to find out the order of the reaction.

J. M. Burgers, USA

2746. Bollinger, L. E., and Edse, R., Effect of burner-tip temperature on flash back of turbulent hydrogen-oxygen flames, *Indust. Engng. Chem.* **48,** 4, 802–807, Apr. 1956.

In a previous investigation it was observed that the reproducibility of flash-back points for premixed hydrogen-oxygen flames, burning at

atmospheric and higher pressures, was greatly affected by the length of time in which flash back was reached. Often an apparently stable flame flashed back after it had burned for several minutes, although no change in the gas flows or chamber pressure had occurred. This behavior of the flame resulted in a large scatter in the critical velocity-gradient data. Similar performance was obtained with hydrogen-air flames. It was assumed that the erratic behavior was caused by an increase in the temperature of the burner rim. Later experiments in the investigation disclosed that conditions for flash back were reproducible when water-cooled copper tubes were used as burners.

In this investigation it was attempted to elucidate the effect of burner-tip temperature on flash back of hydrogen-oxygen flames burning at atmospheric pressure. The effects of burner diameter, burner wall thickness, burner material, burner shape, mixture ratio, and ambient conditions on burner-tip temperature and critical velocity gradient were examined. Over 500 tests were conducted to determine the effects of the variables on the burner-tip temperature and velocity gradient at flash back. The principal series of tests was made with burners fabricated from copper.

The general procedure of conducting the experiments consisted of determining the burner-tip temperature and velocity gradient at the burner wall at flash back over a mixture-ratio range of from approximately 25 to 80% hydrogen by volume for each of the burners tested. Burners were selected to show the influence of diameter, wall thickness, material, and convergence of the burner tube.

From authors' summary

2747. Donegan, A. J., and Farber, M., Solution of thermochemical propellant calculations on a high-speed digital computer, *Jet Propulsion* **26,** 3, 164–171, Mar. 1956.

An excellent description of how digital computers are taking up the burden of iterative calculation.

The article describes the programming and use of an EDC digital computer in determining the chamber conditions and combustion gas compression in calculating performance parameters. The EDC computer is similar to the IBM 650, although somewhat slower. In the problem cited, calculation time was cut down from the nature of days to approximately ½ hour. J. H. Davidson, USA

2748. Schatzki, T. F., The solution of the equations for a steady-state, low velocity flame by means of relaxation methods, *Univ. Wisc., Nav. Res. Lab.* OM 853, 133 pp., Sept. 1955.

A study is made of use of relaxation method of Southwell ["Relaxation methods in theoretical physics", Oxford Univ. Press, 1946] for solution of the steady-state flame equation. Detailed consideration is given to three flame types: a one-step decomposition, a chain reaction with high-energy intermediate, and one with low-energy intermediate. The flame equations are presented as a set of algebraic difference equations which are iterated with trial values of the parameters until the desired accuracy is obtained. According to author, the technique is rapid for the experienced operator but is too lengthy if only several solutions are sought.

Reviewer believes that although no physical insight is gained through use of this technique, it may be useful in certain calculational programs involving systematic changes in variables. D. Altman, USA

2749. Cheng, S.-I., High-frequency combustion instability in liquid-propellant rocket with concentrated combustion and distributed time lag, *Jet Propulsion* **26,** 2, 87–92, Feb. 1956.

Paper is a continuation of previous theoretical analysis by Crocco and Cheng [AMR: **5,** Rev. 2713; **7,** Revs. 608, 1972, 2670]. Distributed combustion time lag was found to be slightly stabilizing as compared to concentrated combustion time lag. There is an excellent set of figures, but labeling of stable regions and a table of nomenclature would aid unfamiliar reader. A. A. Putman, USA

2750. Barrère, M., and Bernard, J. -J., Theoretical study of instability of low frequency in combustion chambers burning liquid fuels (in French), *ONERA Publ.* no. 79, 41 pp., 1955.

Authors analyze intrinsic stability in relation to the combustion time lag and its interaction index. The effects of nonuniform temperature distribution and the convergent section of the nozzle are treated. They then consider the stability of the chamber plus injection system, introducing the elasticity of the feed line and the compressibility of the propellant. A general criterion of stability is defined by writing the interaction index as an explicit function of the critical frequency. This is shown to be possible for both mono- and bi-propellant systems.

From authors' summary by G. K. Adams, England

2751. Rex, J. F., Fuhs, A. E., and Penner, S. S., Interference effects during burning in air for stationary n-heptane, ethyl alcohol and methyl alcohol droplets, *Jet Propulsion* **26,** 3, 179–187, Mar. 1956.

Paper represents an attempt to evaluate experimental interference effects during burning of adjacent stationary droplets of liquid fuel (2–5 droplets burning in close proximity). The evaporation constant K' was correlated experimentally with flame shape, burning rate, droplet diameter, and distance between burning droplets. The most important experimental results are (1) the evaporation constant K' is invariant with time for two burning droplets in close proximity and also for the center droplet of a five droplet array; (2) the absolute value of K' is not determined by chemical composition alone but depends also on droplet arrangement.

The experimental data cannot be explained on the basis of existing theoretical studies for single-fuel droplet burning. According to the authors, the diffusional model for heterogeneous burning of single-fuel droplets will require revision and extension before burning of droplet arrays and sprays can be understood quantitatively. The effective value of K' for a spray evidently depends not only on the fuel-oxidizer system but also on the injection pattern. Therefore, future fundamental studies should be carried out with injector configurations of the type used in service models. J. M. Singer, USA

2752. Goldsmith, M., Experiments on the burning of single drops of fuel, *Jet Propulsion* **26,** 3, 172–178, Mar. 1956.

The mass rate of consumption of suspended drops of liquid fuel (*n*-heptane, ethyl alcohol, benzene, toluene) burning under the influence of varying oxidizer concentration, increased pressure, elevated temperature, and forced convection was measured. An important correlating factor is the evaporation constant K' which is independent of drop size and characteristic of fuel-oxidizer system. Experimental results for each condition were compared with the theoretical calculations based on the concept of a heterogeneous diffusion flame, with burning rate controlled by heat and mass transfer. While there was satisfactory agreement between experiment and theory for the effect of increasing oxygen concentration, predicted theory did not account for the experimental results obtained from the influence of increased pressure and increased ambient temperature.

The diffusion theory explanation represents a useful approximation; however, where there are slow rates of chemical reaction or extensive decomposition of fuels without oxidizer, the basic assumptions may be inapplicable. Attention is called to the practical importance of the relationship between single droplet burning and fuel spray combustion behavior. J. M. Singer, USA

2753. Townend, D. T. A., The combustion of solid fuels, and the aims of flame radiation research in relation to the burning of pulverized coal, *Ingenieur* **68,** 14, W. 41–W. 48, Apr. 1956.

2754. Powell, E. M., High-capacity two-furnace boilers, *Combustion* **27,** 10, 42–46, Apr. 1956.

2755. Saunders, M. J., and Smith, A. G., Phase contrast observation of flames, *J. appl. Phys.* **27,** 2, 115–117, Feb. 1956.

The phase-contrast principle has been applied to a telescopic system to produce a simple instrument of high sensitivity for studying inhomogeneities in fluid media. As an example of the power of the method, the phase-contrast telescope has been used to study the regions in and around premixed propane gas flames. From authors' summary

2756. Blackshear, P. L., Rayle, W. D., and Tower, L. K., Study of screeching combustion in a 6-inch simulated afterburner, *NACA TN* 3567, 58 pp., Oct. 1955.

As part of a general research program on screeching combustion at the NACA Lewis Laboratory, an investigation was conducted to develop screech instrumentation and to study the mechanism of screech in a 6-in.-diam. simulated afterburner.

Probe microphones were developed that can be utilized to measure the frequency, relative amplitude, and relative phasing of the pressure oscillations at various positions within a screeching combustor. In calibrating these microphones to determine absolute values of pressure amplitude, a new theory is proposed to account for the nonlinear attenuation of high-amplitude sound in tubes.

The acoustic oscillation accompanying screech in the 6-in. after burner consisted of the first transverse (sloshing) mode in the hot gases downstream of the flameholder.

From authors' summary by J. A. Landoni, Argentina

Acoustics

(See also Revs. 2619, 2631, 2749)

2757. Williams, W. E., Diffraction by a cylinder of finite length, *Proc. Camb. phil. Soc.* **52,** 2, 322–335, Mar. 1956.

Diffraction of plane harmonic acoustic wave by hollow circular cylinder of finite length is formulated by extension of Wiener-Hopf technique. Approximate solution is obtained for cylinder length large compared with wave length and explicit results given for end correction to those resonant lengths calculated from elementary, one-dimensional solution. Result for semi-infinite cylinder is shown to agree with that of Levine and Schwinger [*Phys. Rev.* (2) **73,** p. 383, 1948]. Results are compared with experiments of Anderson and Ostensen [*Phys. Rev.* (2) **31,** p. 267, 1928] and differences ascribed to real fluid effects such as viscosity.

J. W. Miles, USA

2758. LaCasce, E. O. Jr., and Tamarkin, P., Underwater sound reflection from a corrugated surface, *J. appl. Phys.* **27,** 2, 138–148, Feb. 1956.

Paper deals with reflection of underwater sound from a sinusoidally corrugated pressure-release surface. Authors critically compare three theories [Rayleigh, "Theory of sound," § 272a; Eckart, AMR **7,** Rev. 330; Brekhovskikh, *Zh. eksp. teor. Fiz.* **23,** 275, 289, 1952]. Theoretical results are compared with experimental measurements of reflection, for various frequencies and angles of incidence, from three sinusoidal surfaces of different geometry faced with cork and floating on the water surface. Best agreement was found for moderate angles of incidence and small surface slopes. Surprisingly good agreement was also obtained for large slopes, violating the assumption underlying the theories.

M. C. Junger, USA

2759. Hunt, F. V., Notes on the exact equations governing the propagation of sound in fluids, *J. acoust. Soc. Amer.* **27,** 6, 1019–1039, Nov. 1955.

An editorial note states that this article will appear as a section in the acoustics chapter of the forthcoming American Institute of Physics Handbook. As a result of aiming at encyclopedic completeness, author has made the article difficult to read, but at the same time he is to be congratulated in getting so much valuable information in an article of twenty pages.

Author starts substantially from the analysis given by Eckhart [AMR **1,** Rev. 408], in which the same problems were attacked by perturbation theory carried as far as the second order, and expressed in terms of nondimensional perturbation parameters. Author defers making approximations as long as possible, with the result that the exposition is more difficult to follow than Eckhart's. The first- and second-order acoustic equations are written down and the order of magnitude of the various source terms is discussed. All terms are retained, including those derived from a functional dependence of the coefficients of viscosity and thermal conduction on the state variables. An account is given of plane waves of finite amplitude, and experimental evidence in confirmation of the theory is quoted. Other matters treated are vorticity and streaming, energy and radiation pressure, absorption and dispersion of plane waves on the basis of Truesdell's work [AMR **7,** Rev. 1531], relaxation processes and sound absorption in a two-fluid mixture, and thermal noise level.

Article is a valuable survey of the state of knowledge in this branch of physics.

J. M. Jackson, Scotland

2760. Brandt, H., A study of the speed of sound in porous granular media, *J. appl. Mech.* **22,** 4, 479–486, Dec. 1955.

This is a very useful and ingenious investigation. Assuming an aggregate of randomly stacked spherical particles of four different sizes as a model, author tries to explain the influence of pressure, porosity, and liquid saturation on the speed of sound through a porous granular substance. Using the Hertz theory concerning the deformation of elastic spheres in contact, author determines the relation between the pressure and volume of the aggregate. It is then extended to the case of the liquid saturation. Bulk modulus is thus obtained and, assuming the value of Poisson's ratio (0.20), the speed of sound, namely the dilatational wave, is deduced. It is also shown how the theory is extended to the case of aggregate composed of nonspherical particles and to that of consolidated medium.

Theory is applied for the prediction of the speed of sound through sandstone under various conditions of pressure and saturation, and the agreement with the experimentally derived result is noted.

A comprehensive bibliography is given.

Y. Satô, Japan

2761. Thiessen, G. J., On the efficiency of an acoustic line source with progressive phase shift, *Canad. J. Phys.* **33,** 11, 618–621, Nov. 1955.

Author discusses the effect of a progressive phase shift along an acoustic line radiator of finite length on the directionality pattern and the efficiency of the radiator relative to a line source which is in phase lengthwise. Using the analyses of P. M. Morse for pressure determination at large distances from an acoustic source,

$$P_{\max} = \rho c Q_0 / 2\pi r \cdot \{\mathrm{Sin}\,[kl/2(\mathrm{Sin}\,\theta - \alpha)]/\mathrm{Sin}\,\theta - \alpha\}$$

which, in optics, represents the directionality pattern of a long slit. Author analyzes effect of phase shift on total energy radiated and concludes that phase variation affects mainly the directionality and that the energy radiated will decrease only when rate of phase variation is in synchronism or larger than the variation occurring along the sonic pulse. While the calculations were performed for an acoustic line source, the technique is applicable to an electromagnetic radiator.

Reviewer believes that this problem is basically a two-dimensional problem of the Maxwellian field from a line source and can be classically treated by a transform method of solution.

N. M. Matusewicz, USA

2762. Lassiter, L. W., and Hubbard, H. H., Some results of experiments relating to the generation of noise in jets, *J. acoust. Soc. Amer.* **27,** 3, 431–437, May 1955.

Some sample experimental results relating to the nature of noise in jets are presented. Previous work is extended to include more detailed information about the jet structure. In this regard, noise data are compared for jets having somewhat different turbulence profiles. High-temperature jets are noted to have different radiation patterns and to be more efficient noise radiators than low-temperature jets. Noise data for the high-temperature supersonic jet of a rocket engine are included for comparison with those of subsonic jets. Some experiments have shown the noise levels at the low frequencies can be markedly reduced by the use of grids in the jet stream.

From authors' summary by P.-P. Heusinger, Germany

2763. Keller, E. A., Noise level and mechanical stresses in plastic sound records, *J. acoust. Soc. Amer.* **26,** 5, 685–687, Sept. 1954.

Residual mechanical stresses in press-polished plastic film material used for the embossing-type sound recording are in many cases responsible for relatively high noise levels. Results of noise measurements of different plastic materials on a 400 grooves per inch recorder are presented. The relation between optically observed stresses and recorded noise level is given. Practical consequences are discussed.

From author's summary

2764. Heaps, H. S., Diffraction of an acoustical wave obliquely incident upon a circular disk, *J. acoust. Soc. Amer.* **26,** 5, 707–708, Sept. 1954.

The calculated diffraction pattern behind a circular disk irradiated by an obliquely incident plane wave of sound is compared with that resulting from a normally incident wave. The total sound pressure re-

ceived by a line receiver is tabulated in terms of its length and position along a certain line. From author's summary

2765. **Becker, E. C. H., The multiple panel sound absorber,** *J. Acoust. Soc. Amer.* **26,** 5, 798–803, Sept. 1954.

The sound absorber is treated as a complex acoustic circuit in which the number of elements is multiplied to increase the absorption band width, particularly at low frequencies. A convenient form of construction is developed from a uniform array of simple cavity resonators set in a plane wall. Zero and pole frequencies are controlled and reduced relative to construction thickness by discrete addition of branch tanks. A common point technique is used for assessing optimum construction form and damping. Because of the large number of design parameters, use is best made of simple, approximate expressions for circuit elements, tempered by measured relations between standing wave patterns and impedance characteristics. For a given level of required high absorption, construction thickness determines low frequency limit and number of elements determines band width. An example of most favorable construction form is given, the performance of which compares favorably with other absorbers. From author's summary

2766. **Galloway, W. J., An experimental study of acoustically induced cavitation in liquids,** *J. acoust. Soc. Amer.* **26,** 5, 849–864, Sept. 1954.

An apparatus has been assembled for the study of sonically induced cavitation in the frequency range of 20 to 40 kilocycles. Radially symmetric standing waves are produced in a spherical resonator driven externally by a magnetostriction transducer. The acoustic pressure within the sphere is measured by a small barium-titanate transducer positioned at secondary maxima of the standing pressure wave. Equipment is provided for measuring the gas content of the liquid being studied.

Measurements of cavitation thresholds as functions of air content, hydrostatic pressure, temperature, and surface tension have been made using different liquids. The highest thresholds measured were 200 bars for water and 140 bars for benzine (petroleum ether).

The air content of the liquid appears to be the dominant factor limiting the maximal negative pressure which the liquid can withstand as long as the air content is greater than 5% of saturation. At lower percentages of air saturation the threshold becomes essentially independent of air content, becoming limited by as yet undetermined factors. From author's summary

Ballistics, Detonics (Explosions)

(See Revs. 2594, 2649, 2666, 2740, 2749)

Soil Mechanics, Seepage

(See also Revs. 2453, 2484, 2485, 2516, 2518, 2709, 2778)

Book—2767. **Széchy, K., and Kézdi, Á. (editors), Memorial to Professor Jáky [Gedenkbuch für Prof. Dr. J. Jáky],** Budapest, Akademiai Kiado, 1955, 200 pp.

Book consists of twelve papers on various aspects of soil mechanics, together with editorial note on the late Prof. Jáky's professional career and list of his technical publications.

It may be pertinent to recall that Prof. Jáky received his early training in soil mechanics in 1927 in the United States, and while there was strongly influenced by Prof. Terzaghi. He built up a pioneer soil mechanics laboratory in Hungary and, during a lifetime of exacting work, continued to publish a steady flow of papers, among which were seven papers to the Second Conference on Soil Mechanics in 1948 at Rotterdam.

First paper is short presentation by Á. Kézdi of a letter by Prof. Jáky disproving some assertions by Coenen about the equilibrium of plastic earth masses. K. Széchy writes on the theory of ground-water lowering, dealing with the form of the lowered water table, the yield of well groups and of partially penetrating wells, and the distribution of flow between well groups in stepped excavations.

Á. Kézdi contributes general survey of bearing capacity and settlement of pile foundations, including tests of model pile groups. Reviewer believes fig. 12c, showing closed failure surface (for deep pile), which never rises to ground level, can only apply to a soil which is not strongly dilatant. In strongly dilatant soil, the failure surface caused by the pile must reach ground level to allow dilation and make way for pile point. B. Pogány considers range of grout injections into soil whose permeability to the grout diminishes with time.

I. Biczók contributes an interesting paper on formation and properties of organic soils and their foundation problems. He considers the ignition loss and Dennstedt (heating in oxygen) methods of estimating organic content, concluding that a content of 5% or over by the Dennstedt method typifies organic soils. His experiments on mixtures of organic soil with inorganic soil show that very little organic matter can cause a large reduction in plasticity index. Reviewer feels value of paper would have been enhanced by consideration of hydrogen peroxide method of estimating organic content.

J. Kopácsy writes on the rupture zones and stresses in slopes. L. Karafiáth's study of influences of consolidation and rate of loading on pore-water pressures and ultimate bearing capacity deals with an aspect of soil mechanics of considerable current interest. His work is based on earlier Russian theory by V. A. Florin.

J. Domján considers embankment failure caused by high pore-water pressures in pervious gravelly stratum underlying relatively impervious silty clay layer. I. Szilvágyi's paper deals with relations between consistency indices and soil properties. One diagram suggests plasticity index is linear function both of percentage finer than 0.02 mm and of the grading. Paper by J. Járay relates liquid limit to total grain surface. A. Balla writes on elastic theory of cylinder loaded uniformly by flexible plate.

Final paper by L. Réthàti considers relative settlements as function of time, particularly regarding interaction of structure and foundation.

Publication of this collection of papers, five years after Prof. Jáky's death, is in itself a tribute to the lasting nature of his work.

T. K. Chaplin, England

2768. **Terzaghi, K., Evaluation of coefficients of subgrade reaction,** *Géotechnique, Lond.* **5,** 4, 297–326, Dec. 1955.

An analysis of factors determining value of coefficients of both vertical and horizontal subgrade reaction of cohesionless sand and stiff clay, including numerical values of necessary constants in equations defining coefficients. Many oversimplifications tend to give orders of magnitude of coefficients. Experimental verification is deduced from literature. J. M. DallaValle, USA

2769. **De Beer, E., and Wallays, M., Critical examination of three recent theories on bearing capacity of soil under spread foundations** (in French), *Ann. Trav. publics Belg.* no. 3, 5–47, June 1955.

Theories and basic hypotheses by Meyerhof (1951), by Lundgren and Mortensen (1953), and by Kohler (1955) are reviewed and analyzed critically. Bearing values obtained using these theories are compared with similar values obtained by applying the combined formula proposed by the senior author (combination of Andersen, Buisman, Mizuno formulas, by De Beer, 1954). The comparison shows that the first of these theories, which accounts for the shearing resistance of the soil located above the base of the foundation, furnishes values of bearing capacity which differ only slightly from those obtained with the A.B.M. formula if h/b is less than 2, (h depth, b width of footing). Meyerhof's formula gives higher values for this ratio than the A.B.M. formula. The authors conclude that Meyerhof's theory represents a very valuable tool for bearing-capacity computations in the case of deep foundations.

The theory by Lundgren and Mortensen [AMR **7,** Rev. 2338] gives bearing capacity values sometimes higher and sometimes lower than those obtained by the A.B.M. formula, according to the values of h and b used. However, for $\phi = 30^\circ$, the differences do not exceed 14%.

For Kohler's theory, authors show that it is based on an expression of the normal component of the pressure on the sliding curve, which contains a very important error on the safe side. Therefore it gives values much lower than those obtained by other formulas.

Reviewer believes that this paper, together with a previous one by De Beer ["L'equilibre limite du sol sous des fondations directes," *Ann. Trav. publics Belg.* June 1954] represents a very important contribution to the clarification and better understanding, from both the mathematical and engineering standpoint, of the older and the more recent theories on bearing capacity. R. Jappelli, Italy

2770. Tokar, R. A., Methods for determination of stability of foundations sliding along cylindrical surfaces (in Russian), *Gidrotekh. Stroit.* **24,** 8, 28–31, 1955.

2771. Pokrovskiĭ, B. I., Soil stability on a slope (in Russian), *Gidrotekh. Stroit.* **24,** 4, 35–38, 1955.

Seeping water emerging on a downstream slope of an earth dam may cause erosion. According to the author, the existing formulas analyzing this condition are incorrect in two respects: They refer to conditions present at the top flow line, where they are not the most serious, and they do not allow for the eroding action of water after it has come to the surface, an effect which cannot be adequately reproduced in the model study. In all this reasoning, the soil is assumed to be cohesionless.

According to the improved formula, derived by author, the safe slope would have to be very flat and therefore uneconomical. The remedy is to cover it with coarse pervious material, or to strengthen it by longitudinal reinforced-concrete ribs.

In the opinion of the reviewer, some of the basic ideas of the derivation are not sound and, in addition, statics is violated. The second correcting measure for strengthening the slopes seems impractical.

A. Hrennikoff, Canada

2772. Soloviev, Yu. I., Stability of structures against sliding along cylindrical surfaces (in Russian), *Gidrotekh. Stroit.* **23,** 8, 34–36, 1954.

The problem of stability of the foundation of a structure or of an unretained earth slope, considering sliding along a circular arc, is usually solved graphically. Author develops an algebraic solution of the same problem. His method, introducing no new principles but evoking some theoretical objections, is laborious and, in the opinion of the reviewer, is inferior to the graphical method. A. Hrennikoff, Canada

2773. Lomize, B. M., Determination of a critical sliding surface of earth dams (in Russian), *Gidrotekh. Stroit.* **23,** 2, 32–36, 1954.

Three charts are given for the design of homogeneous earth banks by the curved slip surface method, based on an analysis in which the critical surfaces are identified by a minimization process using Lagrange multipliers. Examples illustrate the computation of (1) angle of slope for specified factor of safety, etc., (2) maximum height for specified factor of safety, etc., and (3) factor of safety for a given design.

R. M. Haythornthwaite, USA

2774. Shkurenko, N. S., Experimental investigation of the possibility of decreasing power by vibrating the cutter (in Russian), *Zh. tekh. Fiz.* **25,** 4, 700–706, Apr. 1955.

Article deals with cutting of soils, presumably for purposes of cutting trenches for foundations, as experiments were carried out by the Institute of Foundations. An analysis is made of data obtained during experiments, and empirical formulas are established. The conclusion arrived at is that an optimal velocity of vibration of the cutting element can be determined which would result in the maximum possible decrease in power requirements. This optimal velocity is dependent on the speed of cutting, traction effort, weight of vibrating masses, and losses in the vibration transmission. No explanation of the term "velocity of vibration" is given. There are two references to articles by the same author.

J. J. Dziewonski, India

2775. Coutts, J. R. H., The estimation of the specific surface of a soil from mechanical analysis data, *Brit. J. appl. Phys.* **6,** 3, 90–91, Mar. 1955.

A method is described by which an approximate value for the specific surface of a soil can be calculated from particle-size distribution data. Factors affecting the accuracy of the results are discussed.

From author's summary

2776. Holtz, W. G., and Gibbs, H. J., Triaxial shear tests on pervious gravelly soils, *Proc. Amer. Soc. civ. Engrs.* **81,** SMI (*J. Soil Mech. Found. Div.*) Pap. 867, 22 pp. Jan. 1956.

Much needed data are given regarding the shearing resistance of mixtures of sand with varying percentages of gravel and crushed rock. Effects of density, percentage of sand, gradation, particle size, and particle shape are presented. Mohr envelopes are plotted for normal loads up to 200 psi. Maximum particle sizes vary from #4 sieve to three inches. These extensive tests represent part of a continuing program of research on all types of gravelly soils.

F. J. Converse, USA

2777. Heinrich, G., and Desoyer, K., Hydromechanical bases of treatment of stationary and nonstationary underwater flow (in German), *Ing.-Arch.* **23,** 2, 73–84, 1955.

General study of the flow of ground water: the consideration of the different forces working on the water and on the aquifer gives an equation generalizing the law of Darcy. Authors consider the different boundary conditions and deduce, from the established generalized equation, the calculation of the unsteady flow of ground water. They find equations which will be used in a following paper for the study of different practical problems.

Authors admit different hypotheses from some investigators. They neglect the compressibility of the fluid and of the aquifer (n is not a function of t), while Theiss, Jacob and others think that these two variations cannot be neglected in the study of practical problems.

L. J. Tison, Belgium

Micromeritics

(See also Revs. 2564, 2709, 2760, 2767, 2777)

2778. Biot, M. A., General solutions of the equations of elasticity and consolidation for a porous material, ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55-A-7, 6 pp.

Equations of elasticity and consolidation for a porous elastic material containing a fluid have been previously established [M. Biot, Jr., *J. appl. Phys.* **12,** p. 155, 1941, and AMR **9,** Rev. 602]. General solutions of these equations for the isotropic case are developed, giving directly the displacement field or the stress field in analogy with the Boussinesq-Papkovitch solution and the stress functions of the theory of elasticity. General properties of the solutions also are examined and the viewpoint of eigenfunctions in consolidation problems is introduced. From author's summary J. S. Aronofsky, USA

2779. Bucker, H. P., Jr., Felsenthal, M., and Conley, F. R., A simplified pore size distribution apparatus, *J. Petr. Technol.* **8,** 4, 65–66 (Tech. Note 329), Apr. 1956.

2780. Harmsen, G. J., The concept "hydraulic radius" in porous media, *J. Petr. Technol.* **7,** 11, 53–60, Nov. 1955.

For isotropic porous media it is shown that the ratio of total pore perimeter to specific surface per unit of bulk volume equals $\pi/4$. Specific cases of cylinders packed with spheres of equal radius and of cylinders packed with equal particles of arbitrary size are considered analytically. The general case for any isotropic porous medium, consolidated or unconsolidated, is also treated. Results are discussed from standpoint of Kozeny's equation as derived by Carman [AMR 1, Rev. 1652]. S. R. Faris, USA

2781. Vasil'ev, V. A., On the shape of the underground saturation line between two drains on an impervious layer, in presence of infiltration (in Russian), *Prikl. Mat. Mekh.* **19,** 1, 106–107, 1955.

Problem is two-dimensional. Drains (or sinks of width l) are equally spaced on the x-axis. Medium (upper half z-plane) is homogeneous. Saturation line is boundary where equilibrium state between water fed through percolation and that carried away through drainage holds.

Author maps hodograph plane conformally onto half-ζ-plane Velocity vector is quotient of two linear combinations (Polubarinova-Kočina) of hyperbolic functions of auxiliary variable $\tau = aF$ (F is elliptic integral first kind). Separate integrations of z_τ and w_τ (w complex potential) coupled with boundary conditions yield parametric equations of saturation line. It is an ellipse with semi-axis b and L, (2 L distance between drains), with $b/L = (\epsilon/\kappa)^{1/2}$. A plot is given of streamlines and equipotentials for case ϵ (percolation coef) $= \kappa/16$ (κ drainage coef).

G. H. Beguin, Switzerland

2782. Worster, R. G., and Denny, D. F., Hydraulic transport of solid material in pipes, *Proc. Instn. mech. Engrs.* **169,** 32, 563-586, 1955.

The growing interest in the hydraulic conveying of solid material in pipes has brought to light the lack of data for the design of these systems. To meet this need, extensive research work has been undertaken both in Britain and overseas and the more important results are summarized.

The flow of mixtures in horizontal pipes is a complex phenomenon not very amenable to theoretical study. It has been found possible to correlate data obtained over a fairly wide range of conditions and the flow in vertical and sloping pipes is also mentioned.

The passage of solids through machines and pipes leads to breakage of the particles and wear of the metal parts. Some test results and conjectures on this are given.

Because high pressures are required for long-distance hydraulic transport or for vertical lifting through pipes, the practical problems of pumping solids are severe. These are discussed with special reference to coal-feeding devices. From authors' summary

2783. Donoughe, P. L., and McKinnon, R. A., Experimental investigation of air-flow uniformity and pressure level on wire cloth for transpiration-cooling applications, *NACA TN* 3652, 28 pp., Jan. 1956.

Brazed and calendered stainless-steel wire cloth was tested for permeability, strength, and air-flow uniformity. Compared to sintered materials, the wire cloth offered a wider range of permeability and greater strength in one direction, but the permeability was very sensitive to calendering tolerances. Air-flow measurements at different pressure levels and exit pressures were made to determine the influence of altitude. A 20 × 250-mesh cloth was tested for air-flow uniformity at a permeability coefficient of 10^{-9} sq in. Weight flow through meshes of 20 × 200, 20 × 250, and 28 × 500 was measured for exit pressures of 8.82 to 36.8 psia. A 20 × 200-mesh cloth was used for strength and permeability measurements.

Disks of wire cloth 1.31 in. in diam were sealed between two flanges of a piping system. Air at 120 psig was filtered and passed through a pressure regulator, a rotameter, and the test specimen. The pressure on each side of the wire mesh was measured. Strength was measured in a testing machine at a constant rate of loading.

Air-flow data were correlated by plotting a "pressure-drop parameter" versus a "corrected mass flow". For a 20 × 250 sheet reduced 36% in thickness, a ± 5% uniformity of flow occurred; for one reduced 40%, some data showed 30% less mass flow than other data because of variations in final thicknesses.

Changes in exit pressures caused air-flow changes of a few per cent or less.

The change in mass flow for a brazed cloth compared to an unbrazed cloth depended upon the thickness reduction. For a 42% reduction, the former passed about 20% of the latter; for a 23% reduction, the flows were nearly the same.

Reduced tensile strengths in one direction of the wire cloths were about 1.5 to 3 times the strengths of porous sintered materials.

Present article is a continuation of the work reported in *NACA RM* E51H23, 1951. C. R. St. Clair, USA

Geophysics, Meteorology, Oceanography

(See Revs. 2574, 2617, 2634)

Lubrication; Bearings; Wear

2784. Grinnell, S. K., and Richardson, H. H., Design study of a hydrostatic gas bearing with inherent orifice compensation, ASME Ann. Meet., Chicago, Ill,, Nov. 1955. Pap. 55-A-177, 19 pp. + 22 figs.

A theory applicable to the design of full journal bearings, hydrostatically supported on gas at low friction and high speeds, is developed. The gas (air) is distributed around the journal through radially directed orifices surrounding the journal which are fed from an annular ring. This pressure supply configuration is referred to as inherent orifice compensation.

Several simplifying assumptions enabled the authors to arrive at a realistic model simple enough to permit of mathematical analysis. Data obtained with the simplified flat-plate bearing are plotted in terms of dimensionless ratios. This information as well as the experience gained with the plate bearing are then used to derive a full journal-bearing theory. A full journal bearing is designed accordingly and fabricated.

Experimental studies of this bearing reveal promising results. The load capacity and weight flow rate are found to agree within 20% of the predicted values. J. P. Vidosic, USA

2785. Osterle, F., and Saibel, E., The spring-supported thrust bearing, ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55-A-195, 7 pp. + 2 figs.

The slider bearing with the bearing a flexible plate mounted on stiff springs is analyzed for its load-carrying characteristics. An algebraic expression is obtained for the increase in load-carrying capacity; a single numerical result is worked out, the increase being 3% for the selected conditions. G.D.S. MacLellan, England

2786. Osterle, F., and Saibel, E., The rheostatic thrust bearing, ASME-ASLE Lubrication Conf., Indianapolis, Ind.,Oct. 1955. Pap. 55-LUB-6, 8 pp. + 3 figs.

Paper gives a theoretical analysis of the load capacity and frictional torque characteristics of a thrust bearing which consists of a plane annular shaft end, rotating at a small distance from a flat surface, with grease supplied under pressure to the center of the annulus. The grease is treated as an ideal Bingham plastic. From their analysis, authors conclude that load capacity and torque are greater than for the same bearing supplied with oil which has the same "mobility" (reciprocal viscosity).

No justification is given of assumption that radial flow can be treated independently of circumferential flow in the determination of the thickness of the nonshearing layer of lubricant. There is no reference to experimental work. G.D.S. MacLellan, England

2787. Shawki, G. S. A., Analytical study of journal bearing performance under variable loads, ASME-ASLE Lubrication Conf., Indianapolis, Ind., Oct. 1955. Pap. 55-LUB-16, 10 pp. + 8 tables + 7 figs.

Paper treats effect of applied loads which vary in magnitude and direction upon journal position and friction in an oil-film bearing. Means are given for obtaining numerical solutions, assuming infinite bearing length and no negative film pressures. Pressure and friction forces produced in the positive pressure zone only are considered.

Confirmation of prior work is obtained for special cases of unidirectional and rotating load of constant magnitude. Calculation of load for a given journal attitude is facilitated by tabulated data, but the inverse process of determining the journal path for a given applied-load diagram must be by trial and error.

J. B. Bidwell, USA

2788. Pinkus, O., and Sternlicht, B., The maximum temperature profile in journal bearings, ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55-A-212, 7 pp. + 5 figs.

Authors calculate the temperature distribution which would appear in a full journal bearing of infinite length, if all heat generated by friction would remain in the lubricant, and believe that they can also clarify the conditions along the circumferential center line of a finite bearing. They start from the Reynolds equation and an energy equation, both of which are derived by neglecting gravitational and inertial forces, heat conduction, and heat loss to the surroundings under the assumption of constant temperature, pressure, density, and viscosity across the film. The density is considered as constant, and for the dependence of viscosity on temperature, the law $\mu = \gamma/(1 + \alpha T + \beta T^2)$ is assumed.

Pressure and pressure gradient are determined from Reynolds equation. Solving that, authors suppose that viscosity is constant also in circumferential direction, and use boundary conditions which correspond to a full bearing and are valid only if no cavitation appears. They insert the so obtained expression for the pressure gradient and the viscosity-temperature law into the energy equation and get the temperature distribution by solving this equation.

Apart from the fact that in full bearings cavitation nearly always

appears, it is not admissible, according to reviewer's opinion, to treat the viscosity as constant in solving Reynolds equation.

U. Rost, Germany

2789. Purvis, M. B., Meyer, W. E., and Benton, T. C., Temperature distribution in the journal bearing lubricant film, ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55-A-216, 12 pp. + 4 figs.

Whereas the isothermal flow in a journal bearing is well known, the problem of the adiabatic flow could not be solved satisfactorily hitherto. Authors try to obtain a solution for this problem for an infinite as well as for a finite bearing. As initial equations, they use Reynolds equation and an energy equation derived by Cope under the assumptions that gravitational and inertial forces can be neglected; that temperature, pressure, density, and viscosity are constant across the film; that no heat leaves the lubricant; and that conduction of heat can be neglected. They take exponential laws for the dependence of viscosity and density upon temperature. Whereas authors consider the dependence of density on temperature in the energy equation, they integrate the Reynolds equation under the assumption of constant density.

For the case of an infinite bearing they obtain an expression which represents the temperature distribution, but contains the eccentricity ratio and the film thickness at point of maximum film pressure. With that authors are content and leave the problem unsolved, because the named quantities are not known for the present, and cannot be determined before solving of Reynolds equation with consideration of a viscosity distribution corresponding to the obtained temperature distribution.

To get a solution for a finite bearing, authors neglect in the Reynolds equation, besides the density-temperature dependence, the portion of the flow due to circumferential pressure gradient. According to reviewer's opinion, this neglect is not admissible, because, in the remaining equation and for the following calculation, essential term representing the portion of the flow due to the pressure gradient along the length is always smaller than the neglected term. Authors are content again with the presentation of a temperature distribution containing quantities which can only be determined by solving the Reynolds equation.

U. Rost, Germany

2790. Lewicki, W., Some physical aspects of lubrication in rolling bearings and gears, Parts I, II, *Engineer, Lond.* **200,** 5193, 176–178; 5194, 212–215, Aug. 1955.

Present article reviews the author's recent theoretical and experimental work on the rolling-contact mode of lubrication, on the basis of his hydroelastic lubrication theory (1954). The lubricant film thickness (order 10^{-4}cm) is computed from the measured mutual inductive capacitance of the bounding surfaces of two cylinders which are totally immersed in the lubricant, pressed together externally, and rotating against one another without sliding. A very good agreement is obtained between the observed value of film thickness and the predicted one, over the whole experimental range of rolling velocity and Hertzian stress. The film thickness varies from 2.5μ to 1.5μ, while the corresponding Hertzian stress increases from about 1900 kg/cm^2 to 4200 kg/cm^2.

In the course of preparatory experiment using ohmic resistance method, several new phenomena are observed. Author points out that the inconclusiveness lies in presenting experimental data without any reference to the temperature, the skidding of rolling elements, and the effect of surrounding air. Even after these sources of errors are prevented, the measured ohmic resistance of film gives only a 10^4th of the expected value. So the author claims that the experimental evidence of the prevailing boundary-lubrication theory is inconclusive, and that the thicker-than-molecular films can occur, even under the conditions of an extreme surface stress.

H. Mii, Japan

2791. Cole, J. A., and Hughes, C. J., Oil flow and film extent in complete journal bearings, Inst. Mech. Engrs., Preprint, 15 pp., 1956.

That lack of agreement exists between theoretical treatments and experimental measurements of friction and lubricant flow in journal bearings is well known. A possible explanation may lie in the incorrectness of assumptions made in the theoretical treatments regarding the angular extent of the pressure film. An exploration of this factor, using transparent bearings and photographing the oil film under ultraviolet irradiation, is described. Photographs are given showing qualitative results of great interest, particularly regarding the breakdown pattern of the lubricant film and the manner in which lubricant is carried through the unpressurized region of the bearing. Illustration of the effect of oil supply pressure and inlet grooving of the bearing should be of great interest to designers.

Quantitative study of the results shows that the film usually commences and terminates later than assumed in most theoretical treatments. Measured lubricant flow is also lower than the amount predicted in theoretical treatments, but it is demonstrated that Barnard's method [*Indust. Engng. Chem.* **18,** p. 460, 1926] of dividing total bearing outflow into a feed-pressure-induced component and a hydrodynamic component enables the results of the experiments to be presented in a consistent manner. The logical consistency of the quantitative treatment is marred by the fact that eccentricity was not measured but, in the analysis of results, was estimated from previous theoretical treatments. While reviewer believes that this has resulted in no significant error, it is to be hoped that, in further work on this topic, authors will devise a means for measuring eccentricity simultaneously with the other variables.

F. T. Barwell, Scotland

2792. Kauppinen, T. S., and Carter, R. H., Load ratings for miniature ball bearings, ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55-A-117, 6 pp.

New graphical data are presented for computing load ratings of miniature ball bearings of the radial, pivot, thrust, and self-aligning types. Standardized methods for evaluating load ratings, based on dimensional and geometric characteristics of larger ball bearings, are for the first time applied specifically to ball bearings in the miniature range below 3/8 in. OD. A brief review of the method for determining equivalent radial load for combined loads is given. The actual design load for a typical miniature radial ball bearing is calculated from basic dimensional data for combined radial and axial-load components.

From authors' summary

2793. Lane, T. B., The lubrication of friction drives, ASME–ASLE Conf., Indianapolis, Ind., Oct. 1955. Pap. 55-LUB-3, 6 pp. + 5 figs.

Friction drives find frequent application where continuous variation in the speed-ratio of coupled shafts is required. In order to ensure high frictional forces between the power-transmitting elements, they are heavily loaded and lubricants giving a high coefficient of friction must preferably be used. An apparatus is described in which the frictional force between two rotating balls pressed together is measured in the region of speeds about the nominal rolling condition. The frictional behavior of the system is discussed and it is shown that in the contact area there is relative sliding between the surfaces even when the balls are rolling together. This characteristic is a common feature of friction drives and so the apparatus has been used to investigate the effect of lubricants on the coefficient of friction. The conclusion is reached that the temperature coefficient of viscosity of the lubricant used plays a large part in determining the efficiency of the friction drive, a large value being beneficial.

From author's summary

2794. Johnson, R. L., Swikert, M. A., and Bailey, J. M., Wear of typical carbon-base sliding seal materials at temperatures to 700° F, *NACA TN* 3595, 22 pp., Feb. 1956.

Wear and friction studies were made to show the effects on performance of temperature, type of mating material, and minor composition changes in typical carbon seal materials. Most data were obtained at a surface speed of 10,000 fpm, a load of 1000 grams on a 3/16-in.-radius specimen, and temperatures to 700F.

Wear of carbon seal materials increased rapidly with high temperatures. The effect of temperature on wear was reduced by using chromium-plated steel as the mating surface rather than stainless or tool steel. In general, the type of carbon and impregnation of the carbon seal material had little effect on wear compared with the effect of the mating metal.

From authors' summary

Letters to the Editor

2795. Re AMR **9**, Rev. 1199 (April 1956) and AMR **9**, Rev. 1497 (May 1956): **Denny, D. F., An experimental study of air-entraining vortices in pump sumps; Markland, E., and Pope, J. A., Experiments on a small pump suction well, with particular reference to vortex formation.**

The above papers were erroneously printed in different issues of AMR. Rev. 1497, which refers to Denny's paper, should have followed Rev. 1199. The editors regret this error.

Books Received for Review

AVY, A. P., Les aerosols, Paris, Dunod, 1956, x + 292 pp.

BAKER, J. F., HORNE, M. R., and HEYMAN, J., The steel skeleton. Vol. II. Plastic behaviour and design, New York, Cambridge University Press, 1956, x + 408 pp. $12.

CARTWRIGHT, M. L., Integral functions (Cambridge Tracts in Mathematics and Mathematical Physics, 44), New York, Cambridge University Press, 1956, viii + 135 pp. $3.50 (paperbound).

Cavitation in hydrodynamics, Proceedings of a symposium held at the National Physical Laboratory on September 14, 15, 16, & 17, 1955, London, Her Majesty's Stationery Office, 1956, v + 448 pp. w/appendix, $5.40 (paperbound).

Creep and fracture of metals at high temperatures, Proceedings of a symposium held at the National Physical Laboratory 31 May–2 June 1954, London, Her Majesty's Stationery Office; New York, British information Services, 1956, iv + 419 pp. $5.60 (paperbound).

DOETSCH, G., Handbuch der Laplace-transformation. Band II. Anwendungen der Laplace-transformation (Lehrbücher und Monographien aus dem Gebiete der Exakten Wissenschaften), Basel and Stuttgart, Birkhäuser Verlag, 1955, 436 pp. DM 56.15.

GARTMANN, H., The men behind the space rockets, New York, David McKay Company, Inc., 1956, 185 pp. $3.95.

GIBSON, J. E., and COOPER, D. W., The design of cylindrical shell roofs, Princeton, N. J., D. Van Nostrand Company, Inc., 1954, xii + 180 pp. $8.50.

HAMEL, G., Mechanik der Kontinua, Stuttgart, B. G. Teubner Verlagsgesellschaft, 1956, 210 pp. DM 29.70.

HAMMOND, R., Foundation engineering, New York, Philosophical Library, Inc., 1956, 192 pp. $10.

MILLER, J. C. P., Tables of Weber parabolic cylinder functions, London, Her Majesty's Stationery Office; New York, British Information Services, 1955, 233 pp. $11.68.

MYKLESTAD, N. O., Fundamentals of vibration analysis, New York, Toronto, London, McGraw-Hill Book Company, Inc., 1956, viii + 260 pp. $6.50.

NEVILLE, E. H., Rectangular-polar conversion tables (Royal Society Mathematical Tables, 2), Cambridge, The University Press; New York, Cambridge University Press, 1956, xxxii + 109 pp. $5.50.

OBERDORFER, G., Die Masssysteme in Physik und Technik, Wien, Springer-Verlag, 1956, vi + 140 pp. $3.80 (paperbound).

OLDENBURGER, R., editor, Frequency response, New York, The Macmillan Company, 1956, xii + 372 pp. $7.50.

PATTERSON, G. N., Molecular flow of gases, New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1956, x + 217 pp. $7.50.

PERRY, J. W., KENT, A., and BERRY, M. M., Machine literature searching, New York, London, Interscience Publishers, Inc., 1956, xi + 162 pp. $4.

PRANDTL, L., Führer durch die Strömungslehre, 4th ed., Braunschweig, Freidr. Vieweg & Sohn, 1956, xvi + 407 pp. DM 19.80.

RAYLEIGH, BARON (J. W. STRUTT), The theory of sound, 2nd ed., New York, Dover Publications, 1956. Vol. I. xlii + 480 pp. $1.95. Vol. II. xvi + 504 pp. $1.95 (paperbound).

ROTHE, R., Höhere Mathematik für Mathematiker, Physiker, Ingenieure. Vol. VII. Schmeidler, W., Räumliche und ebene Potentialfunktionen, Konforme Abbildung, Integralgleichungen, Variationsrechnung (Teubners Mathematische Leitfäden, 47), Stuttgart, B. G. Teubner Verlagsgesellschaft, 1956, 220 pp. DM 19.80.

RUDORFF, D. W., Modern marine engineering, New York, The Philosophical Library, Inc., 1956, v + 154 pp. $4.75.

SEELY, F. B., and SMITH, J. O., Resistance of materials, 4th ed., New York, John Wiley & Sons, Inc., 1956, xvi + 459 pp. $6.50.

SPÄTH, W., Fliessen und Kriechen der Metalle, Berlin, Grunewald, Metall-Verlag GMBH, 1955, 160 pp. DM 13.50.

SCHNEIDER-CARIUS, K., Wetterkunde Wetterforschung (Orbis Academius II/9), Freiburg, München, Verlag Karl Alber, 1955, xvi + 424 pp. DM 27.50.

SHEPHERD, D. G., Principles of turbomachinery, New York, The Macmillan Company, 1956, ix + 463 pp. $10.

WEIBULL, W., and ODQVIST, F. K. G., editors, Colloquium on fatigue, Stockholm, May 25–27, 1955, Proceedings (in English, French, German), (International Union of Theoretical and Applied Mechanics—IUTAM), Berlin/Göttingen/Heidelberg, Springer-Verlag, 1956, xi + 339 pp. DM 46.50.

ZEISE, H., Thermodynamik, Band III/1, Tabellen, Leipzig, S. Hirzel Verlag, 1954, xl + 311 pp. DM 20.

INDEX OF AUTHORS REFERRED TO IN THIS ISSUE

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